MINISTRY OF PUBLIC WORKS, EGYPT.

Report of the Mission to Lake Tana

1920-1921.

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Government Geologist, Anglo-Egyptian Sudan,
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Inspector, Physical Department, Ministry of Public Works, Egypt.

Government Press, Cairo.
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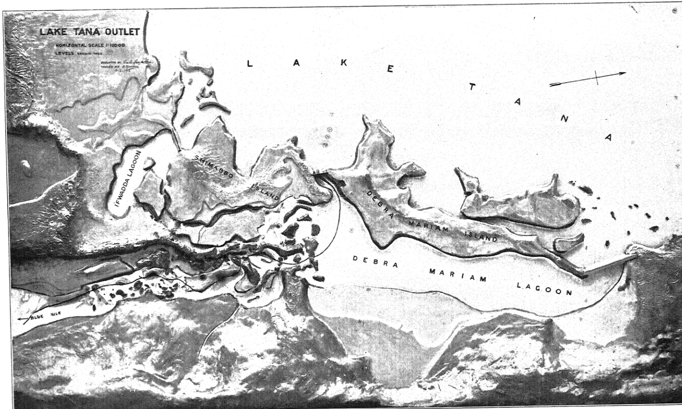
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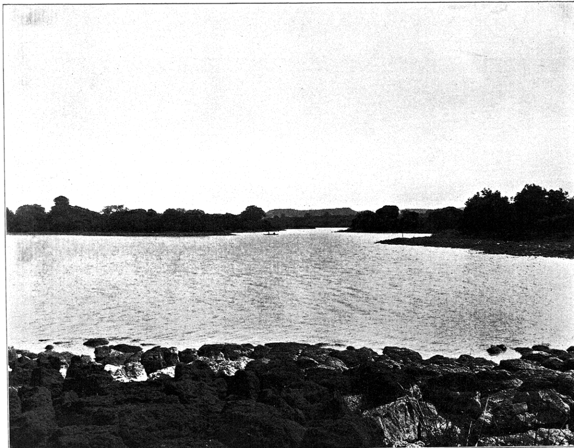
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INTRODUCTION

BY THE UNDER-SECRETARY OF STATE.

The water of the Nile is well in excess of the amount required to satisfy the agricultural requirements of Egypt and the Sudan, except between March and July. During these months, the river is low and its supplies are frequently inadequate to the needs of the summer crops of Egypt, such as cotton and sugar cane, which cannot be successfully cultivated without ample water. More abundant supplies can be provided by the construction of reservoirs on the Upper Nile, where the surplus water of the rainy season and flood may be retained and be let out when it is desired to supplement the flow of the river at low stage. Lake Tana happens to be one of the most suitable sites for such a reservoir, and it is for that reason that regulation of its waters at the outlet, where they flow into the River Abbai or Blue Nile, is desired by the Egyptian Government.

Regulation of the outflow of Lake Tana would also be welcomed by the Anglo-Egyptian Sudan for, though the water supply of the Sudan is enough for the needs of the Gezira plain for some time to come, the full development which may ultimately be admissible in that direction will prove impossible of realization unless the waters of Lake Tana are regulated or other reservoirs are constructed with a similar object.

Under the present natural conditions, Lake Tana gives its greatest contribution to the Blue Nile while the river in Egypt and the Sudan is amply supplied from other sources and gives least when the river is low. If the outflow from the lake were controlled by a regulator, the water which now increases the surplus while water is abundant could be retained in the lake and released when the Nile is low and the needs of agriculture in Egypt greatest.

The probable importance of converting Lake Tana from a natural into an artificial reservoir as one of the measures in a comprehensive programme for regulating the Nile in the joint interests of Egypt and the Sudan has been realized for very many years, and in 1902 the Egyptian Government was authorized by H.I.M. the Emperor Menelik to despatch an expedition, which was led by Mr. C. E. Dupuis, "to visit and collect all possible information concerning Lake Tsana in Abyssinia with a view to deciding whether it could be effectively utilized as a reservoir for the Nile should such a proposal ever come within the range of practical politics."

The results of Mr. Dupuis' visit were embodied in his "Note on Lake Tsana and the possibilities of its Utilization as a Reservoir," published in 1904, as an appendix to Sir W. Garstin's historic "Report on the Basin of the Upper Nile." Considering the short time spent at the lake, the accuracy of his deductions and conclusions is indeed remarkable, for, in almost every case, all the recent observations have merely confirmed his view and shown that the nature and condition of the lake's outlet, as well as the levels and volumes of water to be dealt with, are almost exactly as he estimated them twenty years ago.

Twelve years elapsed before the matter again came up for consideration, and, in 1915, diplomatic negotiations resulted in the despatch of a joint Egyptian, Sudanese and Abyssinian Commission to make further studies of the lake. Our party was led by the

late Col. H. D. Pearson, D.S.O., R.E., Director of the Sudan Survey Department, Mr. A. Burton Buckley being deputed by the Ministry of Public Works to supervise the hydrographical work. Mr. Ph. C. Zaphiro, C.M.G., British Vice-Consul at Addis Abbaba met and remained with the Commission until it dispersed. The Abyssinian members were Likamakwas Abagaz, Atto Takla Hawariat, Fitaurari Melki and Atto Tasfai. Unfortunately political turmoil interfered with the work, but, though no discharge measurements were permitted at the outlet, much useful surveying was done, especially in defining the extent of the area liable to inundation by the rise of the lake water during annual floods, around a considerable part of the shore.

Five years later, *i.e.* early in 1920, it was arranged for the Egyptian Ministry of Public Works to send another Mission to make further studies of the lake. The Abyssinian Government announced its intention of sending two representatives to watch the work and give assistance in the event of difficulties arising. Mr. G. W. Grabham, Government Geologist of the Anglo-Egyptian Sudan, whose services were kindly lent by that Government, conducted the Mission and Mr. R. P. Black, a valued Officer of the Physical Department of the Egyptian Ministry of Public Works, was deputed to accompany him, with special reference to the physical data required. Mr. Grabham has worked for many years in close touch with the Sudan Branch of the Egyptian Irrigation Service. This, combined with his wide scientific knowledge and all-round abilities, rendered him peculiarly fitted to lead the expedition, and, in conjunction with Mr. Black, to report upon its operations.

The authors' instructions were to obtain as much information as possible about the nature and condition of the lake and its outlet, the levels and the volume of the water to be dealt with, and generally to collect all possible physical data having a bearing on the regulation of the waters of the lake. This has been done in a most efficient manner and the results are admirably set out in their report, which opens with an account of the journey and operations of the expedition, then deals, Chapters II to V, with the surveys, meteorology, geology and hydrography of the neighbourhood of the lake; building materials are dealt with in Chapter VI, and this part of the report winds up, in Chapter VII, with conclusions and suggestions as to the form the final work for the regulation of the outflow of the lake might take. In addition, an immense amount of valuable general information is contained in appendices to the report and these deal, among other matters, with the condition of the inhabitants, natural history, routes, and hints for travellers. In general, the report is a mine of information and a monument to the industry and ability of its authors.

The outstanding result of the expedition is the definite confirmation of the general conclusions and deductions made by Mr. Dupuis in 1903. The observations show that in the present unregulated condition of the lake :—

(*a*) The total discharge at the outlet in average years may be estimated at 3,500 millions of cubic metres and this is the volume that could be stored.

(*b*) The discharge at the outlet in normal years varies from almost nothing to about 350 cubic metres a second as a maximum. The discharge of the lake corresponding to the highest levels of the flood amounts to only about one-fiftieth part of the volume entering Egypt and regulation at Lake Tana can make no appreciable difference either to the proportion of silt or to the height of the flood passing Aswân.

(*c*) The range between the high and low water levels of the lake is about one and a half metres.

(d) If the cataract sill at the outlet is lowered by excavation, the manipulation of the reservoir need not involve any increase of the flood level of the lake. Under these circumstances the storage of the volume available in average years would involve a range of about two metres.

(e) The construction of a regulator on a rock foundation to deal with that range of levels, and a maximum discharge of say 500 cubic metres a second should be a relatively simple matter and a light design would suffice.

In drawing conclusions and making proposals, the authors advocate construction at the outlet, of a regulating bridge of 14 openings of 5 metres span, with floor level 7 metres below the natural flood level which, with closure of two other outlets and necessary lowering of the channel downstream of the regulator, would at first allow the water to be run off through a range of three metres below the full level. After allowing for evaporation losses, this range would permit the control of about 6,200 millions of cubic metres of water in the reservoir. Of these, 3,500 millions represent the volume that may be stored annually under average conditions, while the remaining 2,700 million cubic metres would provide the reserve, or over-year storage, wherewith to make up deficiencies in low seasons. It is further suggested that, by additional excavation, water from the reservoir may be run off to a level five metres below the ordinary flood level, increasing the reserve storage to 8,000 millions, which would be enough to meet the deficiencies, even if two seasons of low supply followed in succession. The necessity for this reserve storage, which was first recognized by Sir Murdoch MacDonald, is due to the fact that the supply which the lake can provide annually to supplement the flow of the Blue Nile is a variable quantity and, in some years, may be so scanty that it would fall far short of 3,500 millions of cubic metres. With the aid of the additional storage, not only would the shortage on 3,500 millions of cubic metres be made up, but the river might be still further supplemented.

The authors consider that regulation through a range of three metres below ordinary flood level is the minimum worth undertaking, but that the works should be designed with a view to possible expansion. The extent to which the reserve storage can be useful depends on the supplies available to fill up the lake in years of good rainfall, and also on the ability of the channel downstream of the regulator to draw upon that supply, and it may be desirable subsequently, when need is shown, to be able to expand the range of control from three metres to five metres. The additional two metres of storage would enable the reserve to be increased to 8,000 millions of cubic metres, as noted above, and this, with 3,500 millions for the ordinary annual supply, would give the reservoir a total effective capacity of 11,500 millions of cubic metres.

The effect of the regulation of the outflow and its effect in average years on the present regimen of the lake and on the inhabitants of the shores is dealt with in detail on pages 97–101. The authors suggest that the regulator should be closed except during the period January to April. The highest levels are therefore reached about the end of October, or about a month later than under natural conditions of the lake. The levels would then fall slowly, as a consequence of evaporation loss, until the end of December, when the water would stand about fifty centimetres above the corresponding natural lake level. The regulator would be opened early in January to meet the demands for supplementary supplies in Egypt and the Sudan, and the reservoir would continue, as a rule, to discharge during a period of nearly four months and, at the end of the dry season, the level would fall, as a result of the amount discharged combined with evaporation losses, to a level about fifty centimetres below that ruling for the lake for the same time

under present conditions. The scheme of regulation can only be assumed until the manner in which the water is to be used is exactly known; but the result of the general method is set out by the authors in Diagram 15, and it is seen that the ordinary maximum lake level will never be exceeded when the lake is used as an artificial reservoir.

The authors' estimate of the cost of the regulating works amounts to L.E. 2,300,000, of which the main items are L.E. 1,000,000 for the excavation of the River Abbai channel and tunnel, L.E. 600,000 for the regulator and *sadds*, and L.E. 700,000 is allotted for excavation upstream of the regulator, housing, road clearance and floating plant. It is thought that the works may be completed without having to establish permanent means of communication with the Sudan, but if it is found necessary to connect the lake with Gedaref by means of a railway or a motor road, it is thought that the additional cost may amount to either L.E. 2,500,000 or L.E. 1,000,000 respectively. These figures are all put forward in an entirely tentative manner and the authors do not desire undue importance to be attached to them.

Though it is probable that the works when finally completed will approximate in design, method of operation and effect on lake levels, to those suggested by the authors, I consider that a more tentative and less costly policy than that advocated should be adopted, in view of the deep and expensive commitments involved and the need for fuller physical data, especially in regard to the provision of reserve storage. When the permission of the Abyssinian Government has been given to construct works for regulation, with due respect to the authors' opposing arguments, a more or less temporary structure should be constructed, with closure of spills and some slight improvement of the channel downstream of the work, leaving the construction of the final masonry work and excavation to the full depth of the channel downstream of it until experience has shown definitely what is the best form to adopt and what the cost would be.

Stress is laid on the fact that it is not intended that the contemplated works should cause the lake to rise above its maximum flood level; this however would involve the lowering of the sill of rock which now limits the outflow. Another point to be stressed is that the whole effect of regulation would only be to give slightly higher levels from October to the end of February and rather lower ones from March to the end of September, while the lowest level would only be half a metre lower in the first instance, though this might be increased by another metre later on, and possibly by a further two metres ultimately.

Should permission be given to construct the works for regulation, it is to be noted that the beneficial results which will follow will not be confined to Egypt and the Sudan, for the works in question will enable the highest levels of the lake to be limited, and so safeguard the inhabitants of its shores from the disastrous effects of high floods, while the lower and slightly increased range of levels should decrease the area of swamps and render the neighbourhood more healthy. In addition, the conversion of the Gallabat to Delgi track into a fair mountain road should be beneficial to trade, as also should be the employment of labour and the circulation of the considerable sums of money to be spent in Abyssinia on the construction of works.

Since the waters of the lake can be of no use to the inhabitants for irrigation of its shores, while they would be of considerable value to Egypt and the Sudan, it is hoped that the Abyssinian Government will grant the desired facilities for their regulation at an early date.

In conclusion, I have pleasure in recording the thanks of the Egyptian Government due to the Abyssinian Government for permitting investigations of the possibilities of the lake as a reservoir and especially to H.I.M. the Empress and to H.H. Ras Taffari, the Regent and Heir Apparent, while the unfailing courtesy always shown by Ras Gugsa, Ras Hailu and Dejazmatch Ayalewu, the great chiefs who rule the territories around Lake Tana, has been very much appreciated.

(*Signed*) : P. M. Tottenham,
Under-Secretary of State.

Ministry of Public Works,
Cairo, October 1923.

PREFACE.

At the outset a word is necessary about the pronunciation and spelling of the name of the lake. In European publications it has sometimes been spelled "Tsana"* and sometimes "Tana." The first experience of the traveller to the lake is to find the Abyssinians pronounce the name "Tana" without any "s" sound and that if he speaks the word with an "s" he is unlikely to be understood. The people around the lake say "Tana," as has been recorded by Mr. C. H. Armbruster, and in the *Rivista Geografica Italiana*,† where it is noted that the proper name as spoken by the people around the lake is "Tana." This spelling was adopted by d'Abbadie, and has been used by a number of British, French and German writers. The confusion has arisen from the different values given to this letter "t" in different parts of Abyssinia, words that are spoken with an ordinary "t" in one part being all pronounced with a "ts" in another region. The Abyssinian historian Aleka Taiyeh writes ጣና፡ "Tana," and this spelling has been adopted in Erikson's Amharic Geography. Supported by these authorities, the spelling "Tana" has been adopted in this report with the confidence that it is the most practical form of the name for use in the neighbourhood of the lake.

When the Mission set out, H.E. Sir Ismail Sirry Pasha held the portfolio of the Minister of Public Works. Both he, H.E. Mohammad Shafik Pasha, who was Minister during a large part of the interval, and the present Minister, H.E. Abdel Hamid Soliman Pasha, have followed the work with keen interest and warm support. Sir Murdoch MacDonald occupied the post of Adviser to the Ministry of Public Works at the outset, and any measure of success has been due both to his foresight and guidance and that of Mr. P. M. Tottenham, Under-Secretary of State for Public Works, who has given unstinted help in the composition of this report. Latterly Mr. C. E. Dupuis, sometime Adviser to the Ministry of Public Works, has revisited the valley of the Nile and we have discussed the problems of Lake Tana with profit and pleasure. He went to the lake in 1903, and though his stay was brief, his report remains a monument of careful observations and shrewd foresight. Much in the present report is due to him, and where this has not been acknowledged in detail, it is owing to his ideas having become so familiar that their origin has been overlooked.

In the organization and maintenance of the Mission, a very great debt of gratitude is due to Mr. A. B. Buckley, who unreservedly placed all the knowledge and experience gained during the expedition in 1916 at our disposal. The mission worked under the Projects Department of the Egyptian Ministry of Public Works, and Mr. Buckley as Inspector of that Department had charge of all the arrangements. We soon found, even though almost isolated in remote regions, that we could rely on him to look after even the most trifling

(*) "Report on the Basin of the Upper Nile." Sir W. Garstin, London, 1904, p. 1. A letter is quoted giving the Amharic spelling as ጻና፡ "Tsana," and remarking that though many Abyssinians call it "Tana," the true name is "Tsana." This, however, is not correct.

(†) *A proposito del Nome del Lago Tana*, p. 196, Vol. XVII, 1910.

requirements. Free use has been made in this report of the information collected by Mr. Buckley in the course of his expedition. Thanks are due to Mr. A. W. Wylie, who remained in charge of our affairs when Mr. Buckley happened to be away. Dr. H. E. Hurst of the Physical Department drew up instructions showing the general lines on which information was most required, and from the outset he has continued to guide the Mission on technical matters. Our thanks are due to him for the very friendly and efficient manner in which this has always been done.

Long diplomatic negotiations ably conducted by Major J. H. Dodds, C.M.G., as H.B.M. Chargé d'Affaires at Addis Abbaba, with the Abyssinian Government finally resulted in permission for the Mission to carry out investigations on the shores of Lake Tana. Subsequently both Major Dodds and Mr. Ph. C. Zaphiro, C.M.G., British Vice-Consul at Addis Abbaba, helped us in many ways. Lake Tana is within the sphere of Mr. A. D. Home, British Consul for North-West Abyssinia, and he was always ready to assist in negotiations with the great Abyssinian chiefs, Ras Hailu and Ras Gugsa, as well as in many lesser matters. Mention must be made of Captain M. S. Lush, Secretary at the British Legation, who took a great deal of trouble on behalf of the Mission.

In the Sudan the Mission was greatly assisted by Mr. A. B. B. Howell, Private Secretary to the Governor-General, and by the Authorities of the Egyptian Army, especially Major A. G. Colquhoun, D.S.O., who took charge of the convoy of stores and equipment and brought it under very difficult circumstances to meet us. Mr. C. T. Madigan of the Sudan Geological Survey collected the stores at Khartoum and took them to the frontier at very short notice. On a former occasion preparations had been made to start on an expedition into Abyssinia and the advice then given by Mr. C. H. Armbruster was remembered and proved most valuable. His unrivalled knowledge of the Amharic language is associated with a deep appreciation of the Abyssinians.

In more domestic ways the Mission relied on, and was never failed by, the officials of Kassala and the Fung provinces from their Governors downwards. The several officials who filled the office of Mamûr at Gallabat always replied to our appeals with the greatest punctuality. Both the Bank of Abyssinia and the National Bank of Egypt at Khartoum afforded valuable facilities.

Mr. R. P. Black of the Physical Department of the Ministry of Public Works was selected as the second British official on the Mission and he was given charge of the hydrological investigations. He is entirely responsible for the parts of this report which deal with water measurements. Besides this he undertook a considerable amount of surveying and I have to thank him for whole-hearted support and assistance not only during all the time we were camped at the lake but also in the preparation of this report. The work of the junior staff, G. Yanni Eff. Karkanis and Kilani Eff., surveyors, and Haile Eff. Kibret and Atto Dabba, interpreters, is referred to in various places in the body of the report and it gives great pleasure to emphasize the excellence of the work done by both Yanni Eff. and Haile Eff. The maps as well as many of the diagrams in this report testify to Yanni Eff.'s power of draughtsmanship, and his knowledge of Amharic, begun in the course of the Mission, assisted in the transliteration of many Abyssinian names. In 1922 he passed the Sudan Government's test in Amharic, winning the prize. Acknowledgment is due to the Surveyor-General and his staff for assistance in computations and for the reproductions of maps, diagrams and sections.

In the report, an endeavour has been made to present and record the information collected in the course of the Mission. An attempt has also been made to forecast the

kind of works that may be required to enable the levels of Lake Tana to be artificially controlled so that its waters may be discharged at the proper seasons to help the cultivators in Egypt and the Sudan. The tentative nature of the ideas is repeatedly referred to, but their presentation seems to afford a means of including in a connected fashion a good deal of local information gained during the sojourn at the place where such works will have to be carried out.

Three albums containing approximately four hundred whole plate sized photographs taken in the course of the Mission are preserved in the Ministry of Public Works.

G. W. Grabham.

Khartoum, 1923.

Report of the Mission to Lake Tana.

1920-1921.

CHAPTER I.—Mr. GRABHAM'S NARRATIVE.

As soon as the proposal to send a Mission to Lake Tana was announced, the organization of the Mission under the Projects Department of the Egyptian Ministry of Public Works was placed in the hands of Mr. A. B. Buckley, whose previous experience in Abyssinia proved most valuable. Lists of various requirements had been kept and it was only necessary to arrange for their supply in packages of suitable size for transport by mules. The equipment and supplies obtained in Cairo reached Khartoum on April 12, and were sent on to Wad Medani.

It was at first proposed to go direct from Khartoum to the lake, but the Abyssinian Government requested that the two representatives should first come to Addis Abbaba. I proceeded to Cairo and arrived there on April 20. Passages were obtained by favour of the Naval Authorities on H.M. Transport "Swakopmund" and Mr. Black and I sailed from Suez on May 5, provided with stores and light camp equipment for the journey from Addis Abbaba to Lake Tana. Jibouti, in French Somaliland, was reached on May 11. We unfortunately missed a train and had to wait several days for the next. Abyssinia was entered by rail on May 15 and the capital was reached on May 17. During our stay at Addis Abbaba we were entertained at the Legation by Major J. H. Dodds, C.M.G., His Britannic Majesty's Chargé d'Affaires. His Highness Ras Taffari, Regent and Heir Apparent, received us on May 22, when we were introduced by Major Dodds, while Mr. Ph. C. Zaphiro, C.M.G., the British Vice-Consul, interpreted. His Highness remarked that we had been asked to come to the capital, as no one had been able to explain exactly what interested the British Government in connection with Lake Tana. A brief outline of the Gezîra scheme was given and emphasis was laid on our knowing about the supplies of water available in the Blue Nile, so as to enable the Sudan Government to know the size of the area that could be irrigated. It was pointed out that the Sudan could not take all the water out of the Blue Nile as Egypt lay downstream and her people from time immemorial had depended on the river for water to irrigate their lands during the dry season. It was clear that any scheme which involved raising the level of the lake and consequently flooding its shores would not be looked on with favour. His Highness having learned that I studied questions of water supply, suggested that I might be able to advise the Abyssinian Government regarding a supply for the capital. This was agreed to, provided it did not cause delay in starting on the journey to Laka Tana, and it was pointed out that the Sudan Government would certainly be glad that my services could be of direct assistance in such a matter. His Highness arranged for a guide to show me the various springs and streams in the neighbourhood, and I was able to make a report on the water supply which was translated into Amharic for presentation.

The direct route from Addis Abbaba to Lake Tana involves crossing the Blue Nile and it was essential to start in time to cross it while still fordable. The rainy season was already approaching and the river would soon rise. With the assistance of Mr. Zaphiro, preparations were made for the journey and on June 10 we set out from the Legation and camped at Gefersa, a few miles on the way, to await the passes giving us permission to travel and make measurements of the waters of the lake. The delay in issuing the passes arose from difficulties in selecting delegates to accompany us. On June 13 the passes were issued together with a letter from Her Majesty the Empress to Ras Gugsa and another from H.H. Ras Taffari to Ras Hailu. These announced the objects of the Mission, and that M. Hovian and Atto Tasfai had been delegated to accompany us. The start already made had enabled some small deficiencies to be recognized and supplied, and we left Gefersa on June 15. Atto Dabba accompanied us as interpreter.

Meanwhile Mr. C. T. Madigan had taken charge of the personnel and equipment that were to go direct from Khartoum and had taken them to Gallabat, where they were handed over to Major A. G. Colquhoun who was charged with bringing them to meet us in Agaumidir. This party included the two surveyors, Yanni Eff. Karkanis and Abdel Kader Eff. Kilani, Haile Eff. Kibret as interpreter, three chainmen and several police detailed by Kassala Province. Three of the police remained with us at the lake, and the rest, forming an escort, returned with Major Colquhoun. There were considerable difficulties in arranging for the transport of the equipment from Gallabat. The permits to enter Abyssinia were late in arriving, and as the rainy season approached much tact and patience was required to persuade the Abyssinian muleteers who had been engaged, to remain longer at Gallabat. All these difficulties were met and overcome by Major Colquhoun in the most able manner.

The rains had begun in earnest; we had heavy showers before leaving Gefersa, and our first day's route beyond was marked by a heavy downpour which caught us on the road. Rain occurred almost every day, but by good fortune none fell the day before we reached the Blue Nile. The river was crossed on June 22, 1920, when the discharge was measured and found to be 28·6 cubic metres a second. Debra Markos was reached on June 26, and on July 5 we found Major Colquhoun at Injabara where Ras Hailu was making his headquarters. On July 6 we presented Ras Taffari's letter to Ras Hailu, who received us very well and was evidently anxious to help us in any way possible. The surveyors and equipment had remained at Dangila where we arrived on June 9, and I was able to take charge of all that had been brought up for us. On July 10, Major Colquhoun started on his return journey to Gallabat, and on July 12 we left Dangila. The Little Abbai had already risen so much that the direct route from Dangila to Bahrdar Giorgis was no longer practicable, and consequently a course around its head waters had to be adopted. We returned to Injabara where Ras Hailu received us again. A small chief had been giving trouble on the route we had to take, and Ras Hailu, who had sent people to deal with him, would not allow us to start until he had satisfactory news of the situation. Meanwhile, by his orders many streams on our route were bridged, and this we found of the greatest assistance. Ras Hailu ordered that a small official should accompany the Mission and see that we were properly received and entertained. Wherever there was a village near the camp various presents of food were received. We left Injabara on July 22, travelled round the head waters of the Little Abbai on to the northern spurs of the Amedamit Mountains and reached Bahrdar Giorgis on July 29, with about 130 mules transporting ourselves, the equipment and the supplies. This ended the most miserable journey any

of us had experienced. The rain usually began to threaten about midday, generally culminating in a heavy shower in the early afternoon. There was almost always a fine interval before sunset, when the rain came on again for a couple of hours. It was remarkable how quickly the sky cleared after these showers, and it was not uncommon to find the sky almost free of cloud an hour after a heavy shower. The rains or heavy dews left the tents completely sodden and added considerably to the weights of the loads. The early part of the daily route was often through wet vegetation, and on two or three occasions there was rain during the morning, which made travelling most uncomfortable and frequently penetrated the baggage, so that things had to be opened up and dried when opportunity offered. The mules suffered considerably from the muddiness of the steep paths and from difficulties in crossing streams with slippery banks. It can be concluded, that journeys across Abyssinia during the rains should only be undertaken under circumstances of extreme necessity.

At Bahrdar Giorgis a camping place was selected on a plain about a kilometre southwest of St. George's church. This appeared to be clear of any swamps, but at the height of the rains there was no direction in which it was possible to walk more than a few hundred metres without reaching sodden ground. It proved, however, to be the most convenient and best site.

The first object was to measure the discharge of the river; some preliminary explorations were made, a papyrus raft was purchased, and a site was selected at Egirrbar. A gauge site was also fixed on the lake. The first discharges were observed on August 1, 2, 3, and 4. The Blue Nile at the outlet of Laka Tana forms the boundary between the territories of two great Abyssinian chiefs. Ras Hailu had given permission for the work, and we were in possession of a letter to Ras Gugsa who governs the east side. This, however, had not been presented, and until this was done care was taken to confine activities to the west bank, though it was essential to anchor a wire rope on the east bank. On August 3, messages were received from Fitaurari Shumieh and Fitaurari Adami, asking for our credentials and pointing out that we had not permission to work on the east bank. It appeared that particular objection was raised to the pieces of red and white cloth used on ranging rods. These were regarded as flags and presumably were thought to indicate that strangers were taking possession of the country. In point of fact no flag had been used on the east bank, and as soon as the objection was recognized their use was discontinued. Matters were complicated by the appearance of Kaniazmatch Taffera, a small chief from the west side, who had not been informed that Ras Hailu had sanctioned our work. He appeared at the camp in a drunken condition with a band of armed men at the same time as the messengers from the east bank and also demanded our credentials and failing them that the work should stop. He was most offensive, refusing to recognize the permit from the Central Government, and brought home the truth of the local proverb which states that "a dog knows its master but not its master's master." What he ostensibly wanted was to see that permission had been obtained from Ras Hailu, but he was doubtless actuated by other motives, and these were ignored. He was received politely, and returned afterwards to his men whom he instructed to tell the villagers to turn out our riding animals which some of them had undertaken to shelter. The small official sent with us by Ras Hailu's order was still in the camp, but no notice was taken of him. A letter was immediately written to Ras Hailu in readiness to be despatched at dawn on August 4. Another letter apologizing for the delay was written to Ras Gugsa to go with the Empress's letter, and these were sent in charge of Atto Kassa, the mule contractor who had transported us

from Addis Abbaba. The Imperial letter stated that the Mission would be accompanied by M. Hovian and Atto Tasfai, and as neither of these had appeared, though there had been ample time for them to reach the lake, it was felt that awkward questions might be asked and the work might be interrupted pending their arrival. Atto Kassa was evidently a man of tact who would make the best of things on our behalf, and he was ordered to go to Fitaurari Adami, who would see the letters addressed to Ras Gugsa, and therefore would not delay him.

Early next morning when the delegates from the east bank came for my reply and the messengers were being despatched, Kaniazmatch Taffera also appeared ; he had learned that a letter about his interference was being sent to his immediate superior Fit. Amarro, as well as to Ras Hailu, and he begged that these should be stopped, saying that he did not mean what he had said on the previous evening. He was not received in a tent, but he was thanked for pointing out that Ras Hailu had not given us definite permission to measure the water, and it was essential to write and obtain such an authority in case he or any other chief should demand it. Kan. Taffera was clearly very much discomfited and stated that we could go on with the work. All this happened before the eyes of the messengers from the east bank. They were shown the Imperial letter that Atto Kassa, who was to accompany them on the first stage of his journey, was to carry to Ras Gugsa, and in view of the circumstances I told them that we would work that day and then await the reply from the Ras. It was very important to obtain another observation of discharge, and this enabled it to be done on August 4. The following days were occupied in beginning surveys on the west side of the river, and a closer inspection of the channel was made with a view to selecting a site suitable for flow measurements during the flood. Some lines of levels were also put in hand. At this time the inhabitants were clearly very concerned about the intentions of the Mission, and a large crowd which followed me made it impossible to undertake any details of survey work. I could only tell the surveyors what to do, make casual inspections to see that it was being done, and then go on across country drawing the crowd along with me. This, however, enabled a good deal of information about the region to be collected, and in due course crowds diminished and little further interest was taken in the details of our movements.

On August 12, a cordial reply was received from Ras Gugsa, and a few days afterwards Fitaurari Adami and Kan. Hapto came, and arrangements were made regarding work on the east bank. A man selected by the chiefs was appointed to accompany us whenever we visited the east bank, and it was agreed that he should be warned on occasions when it was proposed to cross the river. The opporunity was taken to arrange for an excursion to the east bank, when, in company with Fit. Adami and Kan. Hapto all the principal points of interest were visited and the method of measuring the discharge of the river was shown and explained to them. A discharge site at Burifasas had been selected and the first measurement there was made on August 13. Gauge sites had been selected on the lake and river and daily readings were organized.

On October 4, M. Minas Kherbeguian reached the east bank of the river and on October 5 he crossed to Bahrdar Giorgis. M. Hovian had been unable to start and M. Kherbeguian was appointed instead, as one of the representatives of the Abyssinian Government. M. Minas had left Addis Abbaba about the end of July and consequently had taken more than two months to reach the lake. He had taken a route north-eastwards from Addis Abbaba, along the eastern edge of the Nile catchment, until he was able to reach the lake *via* Debra Tabor, thus avoiding all large tributaries. He

had had a most trying journey with much rain. M. Minas is a skilled engineer and took a keen interest in the work, and much gratitude is due to him for assistance always rendered in the most friendly spirit.

Atto Tasfai, who had taken the opportunity of visiting his estates near Gondar, arrived to pay a visit to the Mission on October 30. He was able to obtain full accounts of all that had been going on both from ourselves and from M. Minas Kherbeguian and he took a keen interest in the method of observing the discharge of the river, even going out in midstream (Photograph 20) on the *tankwa* (papyrus raft) to hear the revolutions of the current meter recorded by the telephone. Just at this time Kan. Taffera appeared again, and under the impression that he had been reprimanded for the trouble he had caused us and had come to make amends he was received politely. However, while yet in sight of the camp after leaving, he met the postmen just arriving from Gallabat with our mail and put both men under arrest. They were sent to various places and the mail was only received about a week later after it had been ransacked by Fit. Amarro. It was an act of gratuitous interference and the only consoling feature was that it occurred when both the delegates from the Abyssinian Government happened to be present at the camp and were witnesses. The occurrence was reported to Ras Hailu. Atto Tasfai proved most helpful, and we were sorry when he departed on November 1 to return to his estates.

Towards the end of the rainy season there was a considerable amount of fever and quite half the men were on the sick list at times in spite of liberal distributions of quinine. M. Minas' camp close by suffered severely and he unfortunately lost two of his retainers who were no doubt weakened by the long and trying journey from Addis Abbaba to the lake. There are very extensive swamps along the lake shore in the neighbourhood of the outlet; on these papyrus and marsh vegetation thrive, and mosquitoes breed freely. This is clear from their abundance among the papyrus. The neighbourhood of the lake is certainly unhealthy from July until the close of the year and even in other months of the year dwellings must be remote from the permanent swamps. Man is not the only sufferer, for the mosquitoes torment mules, especially if they are kept in *zeribas* at night. It was found best to picket them in the open where they would get the benefit of any breeze to keep away the insects. Smoke fires were lit, but during the rains it was impossible to get enough dry materials to maintain the fire all night. In spite of precautions, several animals belonging to M. Minas and several belonging to the Tana Mission died of horse sickness. The villagers at Bahrdar Giorgis do not seem to keep either mules or donkeys. At this season it was reported from Khartoum that the neighbourhood of Lake Tana was to be regarded as a health resort, and this showed what entirely wrong impressions may be gained by visitors with experience limited to a short part of the dry season. Major Colquhoun lost two of his retainers from sickness contracted during the journey with the equipment, or while returning.

Mr. Black was fully occupied in measuring the discharge of the lake until the end of October. It was important to secure a very complete set of records during the rise and crest of the flood. When the rains slackened and the levels began to fall steadily it was only necessary to observe a single discharge each week and he was able to begin to devote his time to surveying. Meanwhile a base had been measured near Bahrdar Giorgis and a number of points were fixed by triangulation to control the plane-table mapping on which Kilani Eff. was working. Yanni Eff. assisted Mr. Black with the discharge observations and levelled along selected lines in the intervals. Subsequently the line of

levels from Kamforo to a point near Bahrdar Giorgis Church was levelled by both Mr. Black and Yanni Eff. and the results proved the substantial correctness of the values already obtained by Yanni Eff. It was clear that Yanni Eff.'s lines of levels to Burifasas and Egirrbar, which he had himself checked, could be accepted. Mr. Black extended the line from Egirrbar to Jirmidi on the river eleven kilometres from the lake. In this way a number of bench-marks were established, and these were marked at first simply by drilling a hole on the flat surface of selected rocks.

On November 10, I left Mr. Black in charge at Bahrdar Giorgis and proceeded to Debra Markos to pay a promised visit to Ras Hailu. The route taken was down the Blue Nile valley to join the main road which crosses the first Blue Nile bridge and goes through Meicha, then over a pass in the Amedamit Mountains to Dembetcha and Debra Markos where I arrived on November 17. Opportunities were taken of visiting the old bridge of Agam Dildi and calling on Fitaurari Amarro, who was the subordinate chief in charge of a large stretch of country between the Amedamit Mountains and Lake Tana. He gave me a cordial reception.

I stayed at Debra Markos until November 24, when a start was made on the return to Bahrdar Giorgis. During my stay Ras Hailu entertained me well and presents were exchanged. He was very interested in the progress of the study of the outlet.

I reached Bahrdar Giorgis on November 30, and found that M. Kherbeguian had decided to return to Addis Abbaba and was making preparations for his journey. He had seen enough of the work and of the outlet to appreciate all the points and was keenly interested in the outlines of a project for controlling the lake. Doubtless he desired to make a full report to the authorities at Addis Abbaba and with the idea that the level of the lake would have to be raised, he asked what steps it was desired to take to survey the shores to ascertain the extent of land which might be flooded. The details of a scheme for avoiding any increase in levels by cutting a channel through the cataracts was then explained, and we were able to go over the ground together. He readily appreciated the arguments in favour of lowering the outlet so as to control the lake downwards, and realized that the works required for the purpose would be simpler than those required for raising the water level. He left on December 17 with full copies of practically all the data and maps already obtained at Bahrdar Giorgis.

I was due to meet Mr. A. D. Home, H.B.M. Consul for North-West Abyssinia on December 7 at Lebbo, where Ras Gugsa was staying, and left Bahrdar Giorgis on December 2. On arrival at Lebbo, the Consul introduced me to Ras Gugsa, who gave us both a capital reception. He asked a number of questions about the investigations at the outlet and also about the sort of structure that would be required. It appeared that popular rumour had stated that a wall about 100 metres high was proposed, and it was realised that if the level of the lake were raised to such an extent many holy shrines, both on the islands and on the shores, would be submerged, and consequently there was a good deal of hostility to any proposal to interfere with the lake. The details of the scheme were explained to the Ras, who immediately saw that no harm would result from the small changes involved and in fact that the people would benefit when some of the marshes around the lake were drained during part of the dry season.

I left Lebbo on December 14, and proceeded to Delgi on the north-west shore of the lake. Mr. Buckley had left a bench-mark on the rocks here in 1916, but I was misled by a rock which I thought to be similar and did not recognize the real one. Anyhow,



No. 3.—Tall Grass on Lower Reef.

a series of lake levels was obtained and by comparison with the mean of simultaneous readings at Bahrdar Giorgis it has been possible to establish the levels of certain points. It was thought that this might be useful in the event of its being desired to obtain records of the levels of the lake without the need of going to Bahrdar Giorgis.

I returned to Bahrdar Giorgis on December 25, and Mr. Home had arrived on the previous day. He stayed until January 7, 1921, and was able to see the manner in which the investigations were being carried on, and the outlines of proposals for using the lake as a reservoir were explained in accordance with the ideas that prevailed at the time. Mr. Home was very helpful in some dealings with small chiefs. Lij Makonnen, Ras Hailu's Aide-de-camp, had arrived on December 19, and remained until the following day on a visit to the Mission, during which he was entertained by Mr. Black.

The weather had become dry, and during my absence, Mr. Black with the assistance of the Effendis, had accomplished a considerable amount of surveying on the river between Kamforo and the lake. The water levels had fallen and it was no longer impossible to move about in some of the cataracts. During January and February, Mr. Black carried his triangulation to the northern outlet, and we sounded and surveyed the river from the uppermost cataract to a point about a kilometre downstream of Kamforo ferry. Favourable conditions for surveying the outlet and the bed of the river extend from the beginning of the year until the end of June. During the other part of the year there is too much water, the currents are too strong and it is dangerous to negotiate some of the cataracts. Much of the time was occupied in cutting lines through the thick vegetation and this involved considerable delays.

The question of replacing Mr. Black and myself had received attention from a time very soon after the date of our arrival at the lake. There was some delay in obtaining permission for the relief party to enter Abyssinia, but Mr. Herbert and Dr. Mitchell were selected before the close of the year. It was arranged that they should travel from Roseires, and Mr. Black, whose health had not been good latterly, was to meet them with a party of mules large enough to bring them up. A pass was required from Ras Hailu before Mr. Black could leave and Mr. Home was able to arrange this matter when he visited Debra Markos in January. Mr. Black left Bahrdar Giorgis on February 25, accompanied by Kilani Eff. and Haile Eff. Kibret. The pass from Ras Hailu had not been received, but it was desirable for Mr. Black to be able to wait several days at Dangila for the contractors to collect the full number of mules. During his stay there, one of the escort shot and killed another man by accident in a drunken brawl in the village. The culprit was promptly imprisoned, and the rifle was impounded as evidence. It was unfortunate that Ras Hailu at this time was occupied with political affairs connected with the arrest of Lij Yassu and was on the point of leaving his own province to visit Ras Taffari in Wollo. The result was that Mr. Black never received a pass, but fortunately he was able to arrange with the local chiefs and he departed from Dangila on March 7, with two hundred mules. The route from Dangila to Roseires has almost no through traffic and a large part of the way is through almost trackless country. Mr. Black's difficulties were increased by lack of water towards the western end, and it proved that reports were misleading in this important respect. Even the Fung province authorities were not aware of the water difficulties. Mr. Black had to traverse it at the hottest time of the year, almost at the end of the dry season, with a large party and the shortage of water was acutely felt. There is a stretch of 24 miles without water between a point on the Dinder and Abu Ramla where an adequate supply appears to exist only at an out-of-the-way spot six kilometres

from the hills. Four *fantasses* sent by Dr. Mitchell met Mr. Black at this point and were of great assistance. Between this and Roseires there is only the well at Gerri and this supply was exhausted long before many of the mules had been watered. The party was obliged to push on with the tired and thirsty mules to Roseires, where the animals walked straight to the water and drank. Mr. Black reached Roseires on March 31, or after practically seventeen days travelling from Bahrdar Giorgis.

Mr. Herbert and Dr. Mitchell were waiting at Roseires and with assistance from Mr. Black and Haile Eff. Kibret, who was invaluable in arranging loads and dealing with the muleteers, they were able to leave Roseires on April 5, and, travelling by the Gubba route, Dangila was reached on May 4. Here there were delays due mainly to some small chiefs, but they left again on May 11, and arrived at Bahrdar Giorgis on May 14, after thirty-two days' travelling.

After the departure of Mr. Black with Kilani Eff. the amount of survey work possible was limited, but discharge observations were continued by Yanni Eff. There was a good deal of stock-taking, etc., preparatory for handing things over to Mr. Herbert, and in the intervals some surveying was done. Some lines were cut through the scrub in readiness for the triangulation already begun, to be carried on. The Mission since its arrival in Abyssinia in May 1920 had lived under canvas and at Bahrdar Giorgis the tents after enduring exposure in the rains and in the dry season were rotting fast. Had there been stronger winds they would have been blown to tatters much sooner. In view of this, materials were collected for the construction of thatched huts. This was a slow process, as most of the spare labour had gone with Mr. Black either as muleteers or escort, and the stock of cash was so low that it was not possible to employ more men. On April 23, the men of Mr. Home's escort arrived with a supply of cash sent from Addis Abbaba. The collection of grass and other materials for the huts proved a capital occupation for these men during their stay, and they were tired enough after work to rest at night and not cause trouble. The attitude of the inhabitants was well displayed in this connection, for as soon as the men began to cut grass anywhere, the people came and set fire to it, with the result that the men had to go farther and farther afield. However, the materials were collected, and before Mr. Herbert arrived, good mess houses for senior and junior staff, three sleeping huts, two kitchens and a wood store, as well as a meteorological screen had been constructed. Such huts are very inflammable and if they do catch fire it is almost impossible to save any of the contents in the conflagration which immediately ensues. For this reason, no records or stores should ever be allowed to remain in them but should be kept in tents. However, it was a great comfort to be able to sit and write in a hut and to avoid the distracting noise of the flapping of a tent in the wind. The mess huts were ready first, and the sleeping huts erected in the positions of the tents which Mr. Black and I had used were first occupied by Mr. Herbert and Dr. Mitchell.

The arrival of a supply of cash has been referred to. At the outset, the Mission never expected to be so long in Abyssinia. The only coin accepted in the neighbourhood of Lake Tana is the great heavy silver Maria Theresa dollar. The supply and transport of this kind of cash is a formidable matter, so that in an out-of-the-way place such as Bahrdar Giorgis it is not easy to obtain fresh supplies. When the original supply brought by Major Colquhoun was exhausted, other sums were obtained from Ras Hailu, who kindly took a cheque on Addis Abbaba in exchange, and the consignment sent by Mr. Home with his police enabled a fair amount to be handed over to Mr. Herbert. However, at one time cash was completely exhausted, and for several weeks it was necessary to borrow

from the men's savings bank, which fortunately happened to have a fairly large sum to its credit.

The weather was becoming distinctly unsettled, and it was important to start soon if my journey to Roseires was to be accomplished without the many discomforts of travelling in the rains. A pass had been obtained from the Foreign Minister at Addis Abbaba, and Mr. Home forwarded this by his escort together with letters to Ras Hailu and Dejazmatch Ayalewu. The former was away from Debra Markos but the pass was sent on to Dejazmatch Ayalewu, who replied courteously and sent a letter addressed to his chiefs instructing them to assist me and let me pass when they were shown the Foreign Minister's seal. Fortunately the Mission was well enough known to the chiefs in Ras Hailu's country, and no obstruction to my passage was raised. Affairs were handed over to Mr. Herbert and I left Bahrdar Giorgis on May 24, taking the route by Gabgabit and Alafa to Dunkur and Roseires. I was able to call on Fitaurari Daboch at Alafa and handed him a fine Cyprus donkey intended for Dejazmatch Ayalewu who rules a large area of country on the west and north-west of Lake Tana. The route from the lake lay through unmapped country, and it has been possible to define the edge of the plateau and also the watershed of some of the head waters of the rivers Dinder and Rahad. There was a good deal of rain. On June 3, the Aima or Dinder at Dunkur proved to be only just fordable and the water level rose considerably almost immediately after it had been crossed. Rain had improved the water supply on this part of the road since Mr. Black had traversed it, but even so, with a party less than one-quarter the size, it did not prove to be abundant, and the road, west of the point where the Dinder is left, is to be regarded as unsafe for large parties with mules, even at this season. Roseires was reached on June 12, and the first-class ward of Makwar hospital was inaugurated on June 27 with a case of malaria certainly contracted in Abyssinia. The party of Abyssinians who had come as escort and muleteers were sent back by the Gallabat route and arrangements were made for the mules to graze until another relief party should require them.

The work at the outlet has since been carried on by Mr. Herbert and Dr. Mitchell, who have made a very prolonged stay under rather trying conditions. Most valuable work has however been done as a result, and complete observations of levels and discharges during the floods of 1921 and 1922 have been obtained, besides the execution of a considerable amount of mapping. The first of these floods at the lake proved to be much the same size as that of 1920, but considerably higher levels were attained in 1922, and it is of great importance to have observations during such a season. Mr. H. G. Bambridge with Major R. B. Black, D.S.O., R.A.M.C., left Khartoum in the middle af January 1923 to carry on the work at the outlet after the departure of Mr. Herbert and Dr. Mitchell. It was decided to close down the work and withdraw the Mission during the dry season of 1924. This has now been done and Mr. Bambridge with his staff left Bahrdar Giorgis on May 7, arriving at Gallabat on June 4. A brief summary of the later results is given in Appendix VI and it is satisfactory to find that they substantiate all the conclusions based on work during the 1920–1921 season. The essential surveys have been completed and we have detailed records of the water levels and volumes discharged by the lake during four flood seasons.

CHAPTER II.—SURVEYS.

Mapping the Outlet.

The equipment at our disposal included a four-inch theodolite by Troughton and Simms. Single seconds could be estimated by micrometers fitted to both circles. The instrument was admittedly small for such accurate readings, and it was found that the micrometer on one side of the horizontal circle was liable to shift by a large fraction of a minute. However, excellent results were obtained when this was recognized and precautions were taken.

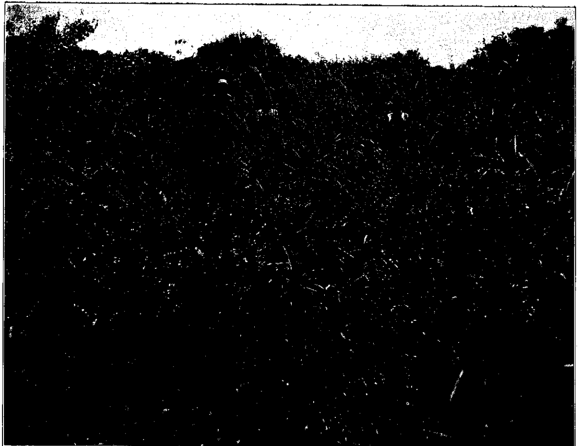
The bases were measured with a New Zealand steel band 120 metres long which had been standardized by the Physical Department in Cairo. Chains were used for measuring traverses and linen tapes were used for distances of detail around the plane-table points.

Box sextants and prismatic compasses were available, but practically all the angles were measured with the theodolite. Two plane-tables were supplied by the Sudan Survey Department and were used with ordinary sight vanes.

With various objects in view surveys on three scales were carried on in the neighbourhood of the outlet. A general map on 1 : 25,000 scale was made, extending from the northern mouth to Arafami falls, Photograph 6, including a small area on the east bank of the river and a larger one to the west.

The detail was plane-tabled by Kilani Eff. and a number of control points were fixed by triangulation. For this purpose a base 1,690 metres long was laid out on the plain south-west of Bahrdar Giorgis Church in a south-west direction, and was measured once in each direction with results that showed the length could be relied on to approximately one part in 40,000. From this base points on the surrounding hills were fixed. The absence of any outstanding points among the cataracts and islands at the outlet makes the tringulation of control points very difficult. With the exception of Tayima Hill and the slopes rising from the east bank there is no high ground offering positions from which the outlets can be overlooked. The surface of the mainland of the west bank and islands at the outlet generally rises only three or four metres above the level of the lake and is covered either with high grass or bush. Photographs 3 and 4 show the character of the herbage and make it possible to appreciate the amount of clearance required before any surveying could be done. Some outstanding trees were selected and branches lopped off until there remained only single ones which could be used as marks for sighting. Photographs 11 and 25 were taken from the tops of two of these selected trees and show the forest covered nature of the ground. To assist in this work, a base 370 metres long on flat ground south of Ifwadda Lagoon was measured with an accuracy of about 1 in 12,000. Most of the angles were measured with the theodolite, but the box sextant had to be used at some of the tree points. In this way the 1 : 25,000 and 1 : 5,000 plane-tabling was controlled.

The 1 : 1,000 scale map was controlled by a very careful triangulation by Mr. Black along the river channel between Kamforo and Debra Mariam Island. The base, 300 metres in length, along the west bank of the river near the ferry was measured with an accuracy of about 1 in 100,000 and a check base along the Upper Reef at the cataracts proved that a high degree of accuracy had been maintained.



No. 4.—High Grass on Lake Shore.

Additional detail was obtained along the level traverses by observing on all three hairs as well as with the compass to obtain the distances and directions of the staves. A careful chain and plane-table traverse was made along the Upper Reef.

Difficulties regarding the selection of points for triangulation due to the vegetation have been referred to. Apart from the amount of time occupied by clearance along lines of observation, the vegetation was a great hindrance to movement and it was often impossible to reach the points by routes across land. The alternative was to travel by water on a *tankwa* or papyrus raft propelled simply by reeds. These craft travel well when new, but progress becomes slow after they have been some days in use, Photograph 7*a*. A good deal of mapping was accomplished during the season but it was done in spite of various hindrances and represents long hours in the field, often tediously directing the clearing gangs.

In view of the trouble occasioned during the expedition of 1916 by attempts to make permanent survey marks it seemed undesirable to attempt to do so in 1920–1921, especially as there was no mistaking the feelings of the inhabitants. Even survey flags were regarded as being doubtful emblems, and consequently, triangulation points on the ground could only be marked by sticks or ranging rods in little piles of stones without any permanent signs to record positions. The best that could be done was to adopt some natural feature which might be recognized, such as a hole or crevice where the position happened to be on rock and not on soil.

These methods were followed in order to secure the greatest amount of information in the limited time at our disposal; only the 1 : 1,000 scale maps could be regarded as complete, so far as they went, at the time of our departure from the lake. The 1 : 5,000 and 1 : 25,000 scale maps were incomplete because the areas mapped on the larger scale were purposely omitted to save re-mapping the same areas. On arrival at Cairo the triangulation data were handed to the Survey Department, where the coordinates of the points were computed to axes oriented according to an azimuth observed by Mr. Black. Subsequently the detail was plotted on the various scales in accordance with the positions of the points and complete maps were produced.

Lake Tana stands 1,840 metres above sea level and the question arose as to the reduction of the surveys to their equivalents at sea level as is usually done in geodesy for representation of the earth's surface on maps. This involves a reduction in the lengths of lines of approximately 1 : 4,000 and, as the maps were primarily required in connection with a scheme for converting the lake into a reservoir, it was decided that the natural values should be adhered to. The reduction would have involved a shortening of the lines to less than their actual lengths on the ground at that altitude, while in the preparation of plans and estimates for works it is essential to deal with the actual dimensions. In this connection it is of interest to note that the surveys of the lake and its surroundings by former travellers have certainly been reduced to their sea-level values for representation on maps; consequently, the areas planimetered from them are likely to be slightly less than the actual areas on the ground. The following are measurements of a 1 : 250,000 scale map compiled from the best authorities, including the late Col. H. D. Pearson's survey made during 1916.

	Square Kilometres.
Total area of Catchment of Lake Tana	16,810
Area of Lake Tana	3,060
Area of Catchment excluding area of Lake ...	13,750

These figures are to be regarded as representing the sea-level values, and consequently, as being about 0·05 per cent too low. The surveys are not yet accurate enough to allow

this proportion to be regarded as of any consequence, and the reason for remarking on it here is to point it out as a factor tending to reduce estimates of areas.

Latitude of Bahrdar Giorgis.

Mr. Black made astronomical observations and determined the latitude of a point at the Tana Mission camp at Bahrdar Giorgis by the method of meridian altitudes to be 11° 35′ 7″, which agrees with the value given by Col. Pearson for the latitude of the church. The azimuth of the line joining the camp point to one of the triangulated points was determined at the same time.

Altitude of the Lake and Aneroid Observations on Routes.

Aneroid observations at Jibouti and Addis Abbaba in May and June 1920 gave an altitude of 2,550 metres at the British Legation, assuming that the temperature of the intermediate air was represented by the mean of the temperatures at the two stations. The British Legation was shown by an aneroid to be 90 metres above the Addis Abbaba railway station, which the engineers had found to be 2,369·5 metres above sea level. The aneroid value for the Legation is therefore 90 metres too high and this rather large error may be due to the unstable weather prevailing during the change from the dry season to the rains. The aneroid value for the camp at Bahrdar Giorgis, based on 2,460 metres as the level of the British Legation and observations in May, June, and August 1920, before and after the journey, is 1,820 metres. On arrival at Roseires aneroid readings were continued at the rest house level with the top of the Nile gauge 455 metres above sea level. There is an established meteorological station at Roseires where a mercurial barometer is observed daily at 8 a.m. Comparison showed that a correction of 0·17 inch was required to make the readings of the mercurial barometer in its position correspond with those of the aneroid at the top of the Nile gauge. Using this correction, further values for the altitude of the camp at Bahrdar Giorgis were obtained by comparing the means of simultaneous readings at both places during the months of January and May 1921 with correction for the temperature of the intermediate air given by observed means at the two stations. The results are included in the following list :—

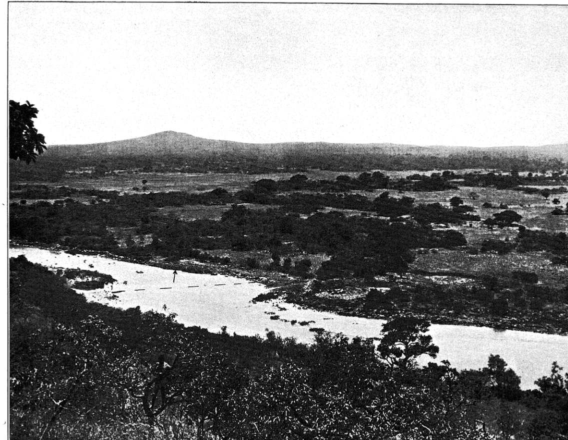
	Metres.
May–August 1920	1,820
January 1921, means	1,810
May 1921, means	1,840

The Tana Mission camp at Bahrdar Giorgis was about 5 metres above the flood level of the lake. Former observers had estimated the altitude of the lake as follows :—

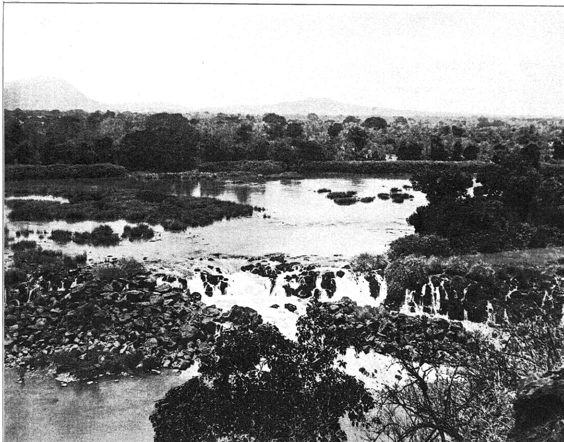
	Metres.
Rohlfs...	1,755
D'Abbadie	1,860
Stecher	1,942
Dupuis	1,760
Buckley	1,780

The mean of the altitudes based on observations in 1920 and 1921 is 1,823 metres. Of the previous observers d'Abbadie's results are probably the most reliable. He placed most reliance on geodetic results,(1) less on the hypsometer, and least on the barometer.

(1) "Géodésie d'Ethiopie," Paris 1873, p. 328.



No. 5.—Egirrbar Discharge Site showing Position of Site III and Bench-mark.



No. 6.—Arafami Falls.

The geodetic value for the shore of Lake Tana is given in his table as 1,855 metres, but on his map the altitude of the lake is given as 1,860 metres. His value, 1,860 metres is 37 metres higher than ours, and giving it an equal weight, 1,840 metres above sea level has been adopted as the altitude of Lake Tana.

Aneroid observations were made along the routes traversed. The altitudes of camps are based on readings at intervals of not less than four hours during the stay, while the altitudes of intermediate points, where it was only possible to make a single observation, have been arrived at by applying a correction for the diurnal variation appropriate to the season. The figures are incorporated in the route reports, and the outline of Section 6 is based on them.

The reliability of these altitudes is shown by the following: several aneroid readings were obtained during the evenings and nights at both Dirre Dawa and Hawash, and altitudes based on the mean of these are 1,223 metres and 961 metres respectively as compared with 1,200 metres and 916 metres accepted by the railway engineers. The boiling point at Injabara was observed with a fairly reliable thermometer and pointed to an altitude of 2,614 metres as opposed to 2,566 metres by aneroid.

Values for the height of Debra Markos are given by observations in June and in November 1921 as follows: 2,398 metres and 2,444 metres. In December 1921, readings were taken at the following places around the lake either actually on the shore or only a few metres above it:—

	Metres.
On shore at north-east corner of lake	1,858
Bank of Dirma on Dembia plain	1,840
On shore near Geraicha Arbatanza at north-east corner of lake	1,840
On shore below spur near north end of east shore of lake ...	1,848
On bank of stream below Warata on Fogara plain	1,864

It appears from these figures that the aneroid altitudes can be regarded as fair approximations. Their reliability certainly depends on the accuracy with which it is possible to estimate the temperature of the column of air intervening between the stations and often this can only be assumed to accord with a gradient.

Levelling and Bench Marks.

For political reasons, during the expedition in 1916 Mr. A. B. Buckley was unable to make any permanent bench-marks. However, he was able to supply details of several points which had been connected by level, and it was possible to identify with absolute certainty one of the best of these at Kamforo ferry near Bahrdar Giorgis. A cross had been painted on the rock and the Abyssinian members of the Commission objecting to it, efforts were made to obliterate the paint. This was difficult on the rough vesicular basalt and the surface was rubbed with some instrument, probably a stone chisel, with the result that the mark was perfectly clear on our arrival in 1920. It appears beside the man's heel on the rock shown in Photograph 7. Had the paint been left undisturbed, it would certainly have weathered off and nothing would have remained to mark the spot. The place was most carefully examined with a magnifying glass and it was impossible to detect any trace of paint. However, it was well known to the people, and we were led to it on the day of our arrival to be shown the " seal " which the party with the Commission in 1916 had left. Kilani Eff. who was with us had accompanied Mr. Buckley and also knew the spot.

Mr. Buckley's barometer and hypsometer observations led him to adopt 1,780 metres as the level of Lake Tana, and based on this the value of the Kamforo bench-mark was found to be 1,778·50 metres or briefly expressed by omitting the first two figures—78·50.

Comparison of a cross-section surveyed by Mr. Buckley near his bench-mark with levels on the ground adds confirmation to the identification. The river is flanked by an alluvial berm on the east bank. The highest point of the berm was found to be 78·84 and lies rather to the south, probably south of the line of Mr. Buckley's cross-section. The highest point on a section through the most prominent part of the bank is 78·75 and this is opposite 78·24 in the lowest part of the hollow which separates the berm from the slopes to the east. The lowest part of the hollow lies to the north and is 78·17. On the most probable line we have therefore :—

	Highest Part.	Lowest Part.
New levels...	78·75	78·24
Mr. Buckley's cross-section	78·81	78·23
Extremes at points near line	78·84	78·17

Even though the series of aneroid observations has subsequently led to 1,840 metres being adopted as the height of Lake Tana above sea level, it was convenient at the time to accept Mr. Buckley's value 78·50 metres for the bench-mark, and all levelling at the outlet has been based on it. Lines of levels were run by Yanni Eff. Karkanis at an early date after the arrival of the Mission. He is an experienced leveller and very soon completed a traverse from Kamforo to the foot of Kobiita Hill as well as a line of levels to the discharge site at Egirrbar with a branch to Burifasas. Part of the crew of staff holders had to be trained from raw Abyssinians and the results of the first traverse from Kamforo to Bahrdar Giorgis village were discarded as unreliable. The lines were all levelled in both directions and closing errors of the order of 1 centimetre in three kilometres were obtained. The mean values were adopted.

Later on Mr. Black and Yanni Eff. Karkanis traversed the line from Kamforo to the bench-mark at Bahrdar Giorgis village. A Cooke-Zeiss and a Cooke instrument were used respectively and every precaution was taken to ensure accuracy. The result showed a difference of 15 millimetres in the value of the Fig Tree bench-mark but only 11 millimetres at the end of the line. The greater difference at the Fig Tree was no doubt due to the difficulty of carrying the line with short shots down the steep shore of the lake. In view of these figures it was felt that the accuracy of Yanni Eff. Karkanis' other lines could be accepted.

The bench-mark positions were chosen on selected rocks, but it was not possible at first to make any permanent marks, though the spot was sometimes bruised by a few blows with a hammer. Later, holes were drilled and subsequently, when circumstances became more favourable, bolts were leaded in flush with the surface to mark the spots. The positions are shown on Maps III and IV and descriptions and values of these bench-marks are given in the following list :—

PLACE AND DESCRIPTION.

Kamforo :—	Reduced Level. Metres.
(*a*) Mr. Buckley's bench-mark, Photograph 7, surface marked by a cross on a shelf of rock on the upstream side of a rocky point standing out into the river and from near which the ferry plies	78·500
(*b*) The ferry bench-mark, a bolt leaded into a hole in a solid looking block on the highest part of the rocky point and a few metres south of (*a*). There are loose blocks around standing higher	79·109



No. 7.—Mr. Buckley's Bench-mark at Kamforo.



No. 7*a*.—The Ferry at Kamforo.

	Reduced Level. Metres
Chara Chara :—	
Surface of rock around hole in rock on east side of cataract...	80·879
Ifwadda Lagoon :—	
Surface marked by a hole in a large flat rock	81·161
NOTE.—This is at the Lagoon Gauge, about 20 metres east of the 80·039 B.M. shown on Map IV. The latter lies on the east side of a slope and is also marked by a drill hole, but the rock could not be relied on for firmness.	
Fig Tree :—	
Surface marked by a shallow hole in ridge of sloping stone. (This is not a very good rock but can be relied on for several years)	80·935
Bahrdar Giorgis :—	
Surface around hole in rock on a mound south of the church and 415 metres south of a conspicuous dry tree north of the church...	86·594
Burifasas Discharge Site :—	
(*a*) Surface around bolt leaded into a hole in a large rock on the ridge near the river	79·701
(*b*) Cross, cut on vertical face of rock at the water's edge just upstream of the discharge site, the Burifasas Gauge	77·680
Egirrbar Discharge Site :—	
Surface of rock around bolt leaded into rock near north end of prominent mass on west bank alongside cataract just below ford and discharge site. The position is shown by an arrow in Photograph 5	75·001
Jirmidi :—	
Surface of rock around hole in large rock on south bank near the ferry	69·544

Levelled sections were made on Shimabbo Island the results of which are included in Section 1, showing the outlet of the lake. When the discharge decreased, lines were run along the Upper Reef and along the sills of the cataracts with the results given in Section 2. The bed of the river between Kamforo and the cataracts was surveyed in detail. At first a series of sections running up the banks to 81·50 metres was surveyed. These involved a very great deal of bush cutting, requiring much time. Moroever they only provided information along their actual lines and conditions made it almost impossible to place them close enough to enable the contours of the river bed to be drawn. It was clear that the river bed was of the greatest importance, since any channel that may be excavated will follow the lowest portions, while the precise outlines of the slopes alongside may be of little interest. The surveying of cross sections was therefore abandoned in favour of methods of soundings. A 300 metres length of wire rope about one-quarter of an inch diameter with graduations at 4-metre intervals was available and proved very useful for traversing across the river. It was easily handled, even in the widest places, nearly 300 metres across, by parties of four or five men at each end. It was convenient to have a smaller party on one bank who could anchor the end of the rope with a stake or by other means while the larger gang on the other bank kept the rope taut. Two plane-tablers were posted at convenient points from which to intersect the positions of the soundings. One worked on the map while the other drew rays on a piece of tracing paper which was afterwards superposed on the map and the intersections identified. The soundings were made from a *tankwa* which moved along the wire rope and stopped at approximately 12-metre intervals. A graduated bamboo about 6 metres long was used in the shallower

parts, while a sounding weight on a chain served where the water was deeper. A whistle was blown at the time of sounding as a signal to the surveyors and one of these replied when both had completed the rays. In places where there were islands and cataracts in the river, the wire rope was put across upstream and the channels were explored with the help of a length of rope tied to the wire rope and by means of which the *tankwa* could be worked up and down the stream. The bottom of the river is often of rock, but it contains sand and mud, and its nature was noted with the soundings. These are recorded in detail on the 1 : 1,000 scale printed sheets preserved in the Ministry of Public Works and the contours on Map IV are based on them.

Delgi Survey and Bench-marks.

A visit was paid to Delgi with the object of finding the bench-mark recorded by Mr. Buckley and also to establish others in case it might be necessary to record the lake levels at that place. The stay extended from December 17 to the morning of the 20th in the year 1920. A gauge stone was selected immediately on arrival and water levels were observed at frequent intervals during the stay. The following are the results :—

	December 17.	December 18.	December 19.	December 20.
Number of readings	10	18	11	1
Means of readings (centimetres)	14·15	14·0	13·5	12·5
Fig Tree gauge at Bahrdar Giorgis (centimetres) ...	42	41·5	40·5	40·5

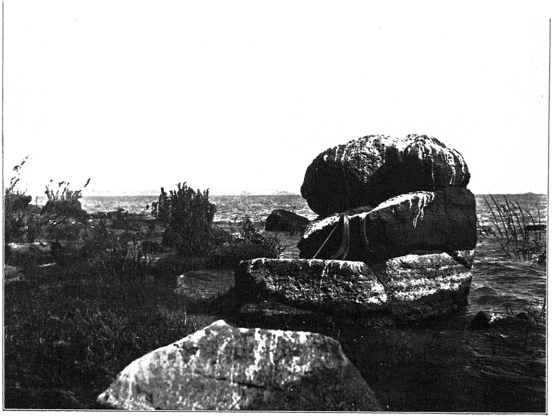
The lake was steady during this period and the seiche did not exceed two centimetres. On the basis of the gauge readings 14 centimetres at Delgi has been adopted as equivalent to 41·5 centimetres at the Fig Tree or 80·415 metres. Consequently the level of the Delgi gauge stone was accepted as 80·275 metres.

The upper limit of the white belt left on the rocks by the flood afforded another means of comparison. With the datum adopted on the basis of lake levels, the white belt was observed at several points as follows :—

	Metres.
Base of "Cottage Loaf" rock	80·917
Rock 20 metres west of "Cottage Loaf" rock	80·907
Rock 6 metres north-west of "Cottage Loaf" rock	80·910
Point on rocks at north end of the Delgi cape	80·924
Another point at north end of the Delgi cape	80·935
Mean at Delgi	80·919
Mean value at Bahrdar Giorgis referred to the Kamforo bench-mark	80·920

Even if this close agreement between the two methods of comparison is partly the result of accident, it is clear that there is unlikely to be any large error in levels based on the gauge readings at Delgi.

Several bench-marks were selected and their positions are shown on Map V. The most important one, referred to as the Delgi bench-mark, is marked by a broad arrow with a hole at its point cut on a mass of rock near the southern point of the rocky shore. Eleven and a half metres to the south of it is a jointed mass of rocks about 1·5 metres high resembling



No. 9.—Rock with Bench-mark on Lake Shore at Delgi.



No. 8.—Three Bench-marks at Delgi.

a cottage loaf in outline and already referred to by that name. At a distance of 9 metres to the north-east of the Delgi bench-mark is a conspicuous boulder referred to later as the Upper Boulder. The Delgi bench-mark has a value of 82·36 metres. The positions of the two points of reference on the "Cottage Loaf" rock are indicated in a sketch at the lower right hand corner of Map V. The lower one has a value of 80·92 and is 6 centimetres south of a hole about 6 centimetres wide on a block with a nearly horizontal surface forming a shelf on the north-west side of the lower part of the rock. This point is marked by the butt end of the fly switch in Photograph 9. The highest point of the "Cottage loaf rock" is towards the north-east and has a value of 81·96. The highest point of the Upper Boulder provides another point of reference and is 83·80. These three points are marked by the men in Photograph 8. The man on the left is standing by the lower bench-mark on the "Cottage Loaf" rock. At the northern end of the rocky shore there is a spur with trees. Just south of the spur is a sandy beach. The trees are marked "d" and "c" on Map V and the highest point on the ridge between these was found to be at 82·21.

To the south-east of Delgi is a storm beach which runs south for some miles. The foot of the slope is fairly represented by 81·30 metres. There is a path along the foot of the slope and it was said that this remains in use during flood. The limit attained by seiches during the 1920 flood is represented by 81·05, and 84·50 and 84·75 are levels just at the top of the little cliff behind the beach and represent the gently sloping surface above.

Surveys of Route.

A perambulator wheel was used for measuring distances on the routes from Gallabat to the lake and from Bahrdar Giorgis to Roseires. The same one was used on all journeys, being taken down by Mr. Black, brought back by Mr. Herbert, and afterwards used on the journey through Alafa to Roseires. It was clear that a correction had to be applied to the measurements to allow for irregularities and inequalities of the paths. This was obtained by comparing the result of plotting the wheel measurements with the existing maps based on triangulation. By this means it was found that a factor 0·92 had to be applied and this agrees with 0·91 based on Mr. Herbert's measurements along the known part of his route near the Blue Nile south-east of Roseires.

The routes lay through almost unmapped country, and among the most important results are the definition of the edge of the Abyssinian plateau over a distance of more than 100 kilometres, and the position near the plateau of the watershed between the Rahad and the Dinder basins. D'Abbadie's triangulation extends from Massaua to beyond the Amedamit Mountains, and adjusting it to modern values on the sea coast, it was found to place Lake Tana on a longitude closely in accord with the position deduced from the traverses to Roseires. The triangulation was adopted and with its aid the new surveys along the routes were compiled on to the maps by Mr. MacIntosh of the Survey Department, Khartoum. The result is shown on Map II, which also includes surveys around the lake by the late Col. H. D. Pearson as well as some route sketches that had not previously been used.

CHAPTER III.—METEOROLOGY.

General Notes on the Weather.

At Dirre Dawa, on May 15, there were crops of durra already about a metre high, showing that some rain had fallen. At Addis Abbaba there was no evidence of recent rain, the ground being parched and dry. The weather became unsettled at the end of May and the first showers were very local. After June 14, during the journey to lake Tana, there was rain almost every day. The mornings were generally fine, the weather began to threaten about midday and rain often fell between 2 p.m. and 4 p.m., after which it cleared and remained fine until sunset. If often rained again during the early part of the night. The afternoon and evening rains were accompanied by some thunder but there was relatively little wind and the tents were never in danger of being blown down. On the few occasions when there was rain before noon, it fell as a drizzle or a steady shower of long duration without thunder, and came on with an overcast sky just as happens in Europe. The rains are essentially not torrential and this is a remarkable contrast to the storms accompanied by violent winds prevailing in the Sudan not far away but at a much lower level. The weather of the rainy season has been well described by Mr. J. I. Craig, (1) who gives reasons for the regular distribution of the rain during the day.

In August a mirage was constantly seen across Lake Tana in the early mornings. This showed that the water was warmer than the air and suggests that at such times the air above the lake must be almost saturated, for if it were not, the water would have been cooled by evaporation. The temperature of the lake can, however, only be studied in deep water, as the shallow water at the margins must be controlled by other factors. Though the shallow waters at the margin of the lake cannot be regarded as representative of the deeper water, the results of the evaporation experiments at the margin are so concordant with the figures derived from other lines of reasoning, that we can regard the losses at the margins and the centre of the lake as closely similar.

There may be a slight land and sea breeze effect at the margins of the lake. On several days in August it was noticed that there was a light south wind in the early mornings changing to the north later in the day. In September and October the wind freshened towards midday and waves arose on the lake. This died away and there was often very little wind in the evenings. Sometimes it was so still at 8 p.m. at the time of the meteorological observations, that a candle burnt steadily in the open without a globe.

August 22 and 23 were conspicuously fine days with north wind prevailing during parts of the mornings and the Piche tubes recorded considerably greater amounts of evaporation, showing that comparatively high figures would prevail as soon as the rains ceased.

It was very common during August and September to find low clouds lying on the hills in the south and a mist in the valley extending to the ground around the camp. The appearance of saturation was borne out by the quantity of moisture condensed on the grass and on cobwebs which became conspicuous. On one occasion towards the end of the month, the Amedamit Mountains were white with hail for a few hours after a storm.

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(1) "Cairo Scientific Journal," p. 409, Vol. II, 1907, *see also ibid.*, pp. 307 and 364.

The period from October 9 to 18, 1920, was very interesting. There had been only about 10 millimetres of rain since the first of the month, but 95·2 mm. was recorded between these two dates. The rains were steady, lasting considerable times and seemed as if they must have fallen over large areas. On two evenings rain began at about 5 p.m. and lasted until midnight. It is unlikely that such falls can have been local. Even if all the storms did not extend over the whole area, rainy conditions prevailed and there were certainly other storms which did not affect the rain-gauge. The prevalence of rain was confirmed by the postmen, who reported storms of rain near Gallabat on four or five days—October 13 to 17. In these circumstances it seems reasonable to regard the record of the rain-gauge as representative. The rain falling directly on the lake must have provided an average of between 27 and 30 millions of cubic metres daily, practically balancing the discharge of the period. Besides this the lake was receiving the contributions of tributaries. These had diminished in volume since the middle part of the rainy season but reports showed that they were still carrying considerable amounts. Messengers crossed the Little Abbai several times during this period and reported that it was fordable above its confluence with the Jamma but was still a strong river. Early in the month M. Minas Kherbeguian crossed a tributary of the Gumara river and estimated its volume as 35 cubic metres a second. Though the streams must have decreased in volume during the first days of the month, the rains of the earlier part of the wet period might be expected to have increased them before October 19. If the direct rainfall is regarded as balancing the discharge of the outlet of the lake, the evaporation losses may be set against the supply from the tributaries, yet this additional quantity hardly sufficed to arrest the fall of the lake as shown by the five-day means of the gauge readings.

The rains of 1920 were generally said to be fair. The crops were certainly good and this was due to the distribution of the rain, which, except for a lull in August, fell evenly over a long period. The last showers were late and may have done some damage by laying the ripening crops.

Towards the end of the rainy season in September and October the intensity of the midday storm was reduced to a threat, but there were some violent thunderstorms in the evenings. Flashes struck unpleasantly close, and on one occasion the concussion was felt. A lightning conductor was improvised near the camp.

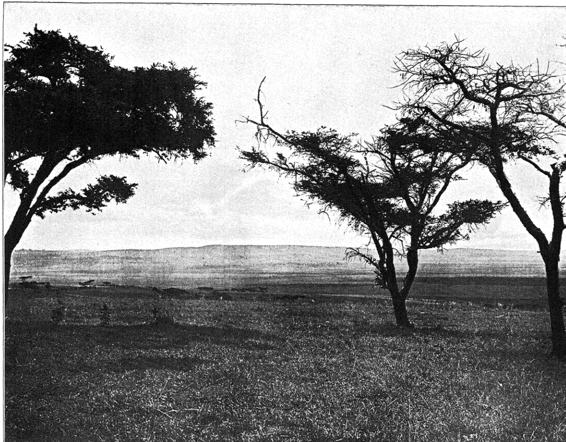
About the end of October, with the onset of the clear weather, the nights became colder, though the maximum temperatures were maintained or even increased. During a journey to Debra Markos in November, the cold at nights was felt acutely immediately the vicinity of the lake was left. At Debra Markos the camping place was chosen in a valley, and probably on account of dampness proved to be much colder at nights than on the ridge where the village stands. There was white frost on the ground in the mornings and small quantities of water were frozen. The thermometer at 8 a.m. was about 16° C., which gives no idea of the cold at dawn. One morning the temperatures observed just before sunrise were, dry bulb 1·1° C. wet bulb 0·1° C., while at 8 a.m. they were 16·0° and 8·1° respectively; at midday they were 20·4° and 10·8° and at 8 p.m. 4·6° and 3·3° respectively, and these may be regarded as fairly typical. The big increase in temperature between dawn and 8 a.m. at this season is explained by the clear mountain atmosphere and the latitude. The sun rises almost vertically, is already quite high at 8 a.m. and passes right overhead at midday, even in winter time, so that though the mornings and nights are cold, the middles of the days and early afternoons are quite warm. There is a much bigger range of temperature during the clear weather of the dry season than during the cloudy weather

of the rains and the monthly mean values given in the table farther on do not indicate the extent to which the cold is felt in winter time.

The nights at Bahrdar Giorgis became decidedly cold towards the end of November and frosts were experienced in January and February. That is, it was not only cold enough for frost, but there was enough moisture to condense and freeze. If the temperature at 8 p.m. during this time is less than 10° C., it is likely that it will be cold enough for frost during the night. As the dry season progressed, the amount of dew became less, until towards March and April, except just after some showers, the ground was so dry that there was no dew.

In November, when the ground became dry, haze began to develop. When the Amedamit pass was crossed on November 13, the air was clear and the lake 45 kilometres to the north could be seen, but on November 28 there was a dense haze which appeared to form a layer with its surface at about 4,000 metres above sea level or almost level with the tops of the Amedamit Mountains. The haze did not persist, and the atmosphere was generally clear from December 7 to 14, when very distant views were seen from Lebbo. The dust haze was observed at Delgi, December 17 to 20, and subsequently. It is generally best seen when the sun's rays are almost horizontal either at sunrise or sunset and forms a belt on the horizon. It shows best opposite the sun but can be seen for at least three quarters of the circle. The colour is steel grey below, shading into red above, then yellow, which merges into the tint of the sky. After sunrise the red fades and the haze is seen as a greyish brown pall with a tenuous surface. The haze of the early part of the dry season must have been due to dust, as the grass was not then dry enough to burn. As the time progressed and grass began to be burnt, the haze became denser. The climax was reached in March, and on the 19th of that month the atmosphere was thick enough to be termed a fog, completely obscuring objects more than three kilometres distant. On one occasion it was noticed that the atmosphere cleared following an alteration in the wind, as if a change had occurred in the electric charge of the atmosphere and the dust had been precipitated.

During the winter and spring, the normal daily routine was for the weather to be calm and almost cloudless at sunrise; a wind from the east or south-east then developed and sometimes became quite strong, five on the scale, flapping the canvas of the tents, and this continued until 11 a.m. or midday, when the wind veered round to the north. Later on in the season some clouds used to develop at about 2 p.m. and the wind continued until sunset, when it changed to the west or died down. The weather in February showed some marked changes. To begin with, the days were clear but there was cloudy weather from the 4th to the 10th, followed by fine weather, which continued until the 26th. Then an unsettled spell began. The mornings were clear but clouds gathered and storms developed about 3 p.m. There was often a lull between 5 and 6 p.m. and a storm would arise after sunset and last until midnight. There were only small showers at Bahrdar Giorgis, but Mr. Black, who was at Dangila, experienced some heavy rain during this time. This broken weather continued until March 10 and afterwards it was fine during the rest of the month. During this later period there were more clouds towards the evening and storms of wind and rain occurred on the hills, but there was no rain at Bahrdar Giorgis. Conditions became more uncertain, but the dust haze diminished and the air was much clearer after the end of April.



No. 10.—Flat Floored Valley near Dembetcha.

Meteorological Observations at Bahrdar Giorgis.

The following observations were taken as far as possible at 08·00, 14·00 and 20·00 hours daily :—

(1) Wet and dry bulb thermometers.
(2) Aneroid barometer.
(3) Piche tubes.
(4) Wind strength and direction.
(5) Clouds.
(6) Rainfall (at 08·00 hours).
(7) Tank evaporimeter floating on Ifwadda Lagoon.

At first no screen was available and temperatures were read on a psychrometer.

Owing to wave action, it was quite impossible to maintain the evaporimeter on the open lake even a short distance from the shore, but this proved quite feasible anchored out in the Ifwadda Lagoon, Photograph 11, where, although the tanks were occasionally sunk by wave action, practically a continuous record of readings was obtained from November onwards. Blanks in the record are due more to native interference than to the action of wind and waves. The evaporimeter consisted of biscuit tins 9″×8″×5″, which were floated in a *tankwa*, as shown in Photograph 12. By sinking the *tankwa* to within 5 centimetres of the water surface, it was possible to maintain equality of outside and inside temperatures within about 1° C., the water outside being about 1° colder at 08·00 hours and 1° warmer during the day. The question of a possible difference of temperature between the lake and the lagoon was considered, and on December 7 a continuous series of temperatures was taken in the lake about 200 metres from the shore (being the distance from the shore of the evaporimeter), from the current meter rating site, near the Fig Tree gauge, to Ifwadda Lagoon, when it was found that the lake temperature varied from 22¾° to 23¼° C. while the lagoon temperature was constant at 23° C.

Reduction of Observations.

Temperature.

No readings of minimum temperatures being available, the mean daily temperature is taken to be the mean of the readings at 08·00 and 20·00 hours, which is probably within 1° of the true mean.

Relative Humidity.

The mean relative humidity is taken to be the mean of the humidities at 08·00 and 20·00 hours.

Rainfall.

Rainfall is expressed as monthly totals in millimetres.

Table I.—Temperature, Relative Humidity, and Rainfall at Bahrdar Giorgis.

Month.	Mean Temperature.	Mean Relative Humidity.	Rainfall.	Prevailing Wind.
	°C.	%	Millimetres.	
August	15·2	84	238	S—2
September	17·3	82	213	S—2
October	17·6	75	104	SE—2·5
November	16·3	73	47	—
December	15·8	64	3	—
January	14·9	51	3	N—2·5
February	16·5	32	4	N—2
March	20·0	37	4	N—3
April	22·1	31	1	N—3
May	21·4(1)	46(1)	60	N—3
June	—	—	135	—
July	—	—	475	—

(1) May 1–23 only.

EVAPORATION.

No completely satisfactory solution to the problem of determining the evaporation from a large water surface has so far been obtained. Readings from Piche and Tank evaporimeters require a reduction factor which can only be determined by an absolute measurement of the evaporation by some other means. Any absolute measurement of the evaporation from a large surface, such as a lake, is complicated by the presence of an unknown factor, seepage.

Experiments carried out at Bombay Water Works in 1893(1) on the evaporation from water surfaces of different sizes gave the following results :—

Area of evaporating surface ...	1 sq. ft. :	10,000 sq. ft. :	Lakes (300–3,000 acres).
Evaporation depth	1·5 :	1·3 :	1

On the other hand, experiments carried out at Denver, Colorado, in 1917,(2) where tanks of different sizes and shapes were compared, gave the followings results :—

(*a*) Circular tanks on land, similar exposure.

Diameters	1 :	3·39 :	12 (feet).
Evaporation depth	1·55 :	1·21 :	1

(*b*) 3 feet square floating tank ... : 12 feet diameter land tank.
Evaporation depth... ... 109 : 100.

(*c*) Evaporation increases by 5 per cent per Fahrenheit degree rise of water temperature.

(*d*) The curve showing the evaporation depth from tanks of different sizes appears to be asymptotic and the evaporation from a large open water surface such as a lake is taken to be 0·99 × evaporation from a 12 feet tank on land.

It is unfortunate that no larger water surface than 12 feet diameter was available in these experiments. By adopting the results, however, we shall not underestimate the evaporation, as there is no *a priori* reason to suppose that the evaporation will increase with increase of area beyond the limit for which experimental data are available.

As no figures were available for the comparison of different sizes of floating tanks, an experiment was carried out in the reservoir at Abbasîya, in which tanks 1 foot square, 2 feet square, and 3 feet square, each 3 feet deep, were floated, protected by rafts to avoid interference by wave action. Subsequently a replica of the tank used at Lake Tana (9″ × 8″ × 5″) was floated in the same manner in the reservoir.

The results obtained are as follows :—

Size of tank,	9″×8″ :	1 foot square :	2 feet square :	3 feet square.
Evaporation depth,	125 :	114 :	106 :	100

(Four months' observations.)

Using the figures of the American and Abbasîya experiments we get :—

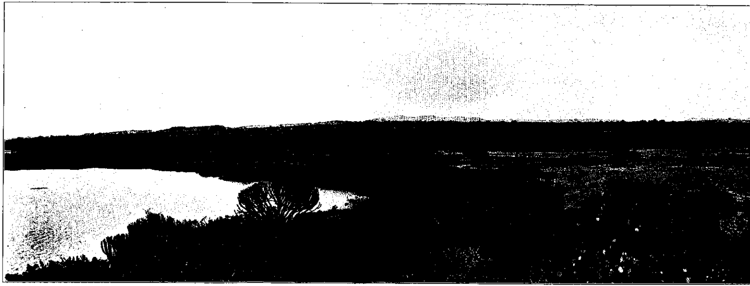
Tank in Lake Tana : Lake Tana.

$$\text{Evaporation depth ratio} = \frac{125}{100}\times\frac{109}{100}\times\frac{100}{99}=1\cdot38$$

or evaporation from Lake Tana = 0·72 × evaporation from the tank.

(1) Q. J. R. Met. Soc., Vol. XX.

(2) "Journal of Agricultural Research," Vol. X.



No. 11.—East End of Ifwadda Lagoon with Kamforo Beyond.

The method adopted for the reduction of the Tana observations was as follows :—

Knowing the discharge of the outlet, a curve was constructed showing the level of the lake as if the outlet were sealed, Diagram 15. The turning value of this curve gives the date on which loss exactly balances influx, which happened on about October 20 in 1920.

Assuming that the loss at this time is about 2·5 millimetres a day and the lake area is 3,000 square kilometres, page 11, the influx is 7·5 million cubic metres a day or about 85 cubic metres a second. Now during the dry season the Little Abbai is the only stream which has any important flow entering Lake Tana. On February 7, 1903, Mr. Dupuis found the Little Abbai discharging about 10 cubic metres a second. On February 28, 1921, a discharge observation about 30 miles from the mouth of the river gave about 5 cubic metres a second, and on May 25, 1921, its discharge was again about 5 cubic metres a second, the river having passed its lowest stage. It is thus possible to construct a time-influx curve showing the influx into Lake Tana during the dry season. An examination of the figures shows that this influx for the months January to May is so small that an error of 50 per cent in estimating its value is of little or no importance.

The total fall of the lake in any period after October 20 is obtained at once from the curve showing the lake level with the outlet sealed. We then have, total fall of the lake in any period + influx + rainfall = evaporation from the lake surface + seepage through the lake floor.

TABLE II.—LOSSES DEDUCED FROM FALL OF THE LAKE.

Period.		Fall of Lake.	Influx.	Rainfall.	Total Lake Losses in Period.	Lake Losses per Day.
		Millimetres.	Millimetres.	Millimetres.	Millimetres.	Millimetres.
December	1–31	110	22	3·3	135	4·4
January	1–31	105	12	2·8	120	4·0
February	1–28	115	6	3·9	125	4·5
March	1–31	145	4	3·9	153	5·0
April	1–30	185	2	0·6	188	6·3
May	1–19	100	1	14·4	115	6·0

Multiplying the figures for the evaporation from the tanks by 0·72 we reduce them to lake evaporation as explained above. Comparing the figures so obtained with the actual lake losses, we see that practically the whole of the lake losses during the dry season are due to evaporation, or in other words the seepage loss during the period of low level is very small. (*See* Table III.)

For a few days the Piche tubes at Lake Tana were hung under a tree. The observations relating to the 08·00—14·00 hours' period can be accepted as reliable but those including times of rain and night are doubtful. In the mornings the papers were found flowing with water and the reading at 8 a.m. was often 0·1 mm. less than at 8 p.m. on the previous night. The excess water may have been either dew or rain. As soon as this was noticed, they were moved to a stand below the edge of the outer fly of an "atmoor" tent, where the exposure was not altogether satisfactory owing to the flapping of the tent on windy days, but the ventilation was probably at least as good as in a double-louvred screen. Later, a thatched thermometer screen was built, and the Piche tubes were moved to it on March 17, 1921. Two Piche tubes were available and both were observed. It was found, however, that one of them, owing to its different capacity, gave readings about 15 per cent greater

than the other. The graduations should represent millimetres of evaporation from the surfaces of the paper disc. One tube proved to be correctly graduated and the readings of the other were reduced so as to correspond.

In Egypt and the Sudan, where Piche tubes have been exposed in double-louvred screens, comparison of observations taken over a period of several years with those of the corresponding exposed tanks have resulted in indicating 0·58 as the reduction factor to be applied to the Piche readings to bring them into relation with evaporation from large sheets of water. The observations at Barhdar Giorgis showed that the corresponding reduction factor is 0·64.

The evaporation depth from a metre square tank floating in a river or reservoir has hitherto been accepted in Egypt as the evaporation depth from the river or reservoir itself. The American experiments indicate that this is of the order of 10 per cent too high, and the experiment at Abbasîya, showing a very large difference between the evaporation from tanks 1 foot square and 3 feet square floating under the same conditions, indicates the danger of using too small a tank.

The adopted figures shown in Table III are not final, but are the best obtainable at present. The figures for the months August to November for which only Piche tube readings are available are doubtful, and it is possible that seepage losses are heavier at higher lake levels.

TABLE III.—EVAPORATION AT LAKE TANA.

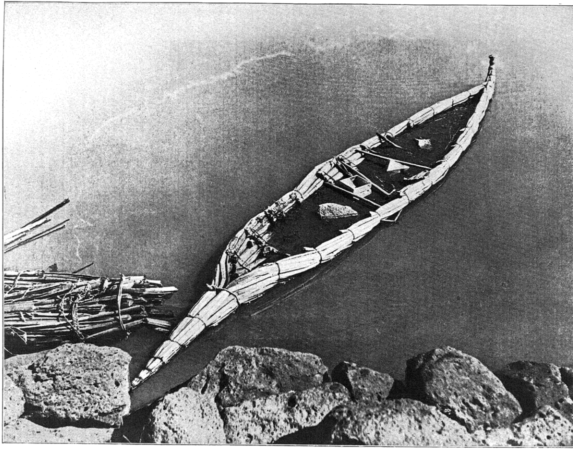
(Millimetres per Day.)

MONTH.	Piche Tube.	Tank.	0·64 × Piche.	0·72 × Tank.	Lake Losses.	Adopted Value Evaporation.
August...	2·1	—	1·3	—	—	1·5
September	2·8	—	1·8	—	—	2·0
October	4·0	—	2·6	—	—	2·5
November	4·8	—	3·1	—	—	3·0
December	5·4	5·4	3·5	3·9	4·4	4·0
January	6·8	5·5	4·3	4·0	4·0	4·0
February	9·4	7·0	6·0	5·1	4·5	5·0
March	9·9	7·4	6·3	5·3	5·0	5·5
April	9·5	8·2	6·1	5·9	6·3	6·0
May	7·6	8·6	4·9	6·2	6·0	5·5
June	—	—	—	—	—	4·0 } (1)
July	—	—	—	—	—	2·0 }

Incidence of the Rains on the Abyssinian Plateau.

The work of the Tana Mission permitted a few observations bearing on the distribution of rain on the Abyssinian plateau. The first arises from the measurement of the volume of the Blue Nile at Kutai, on the route from Addis Abbaba to the lake, on June 22, 1920, when the discharge was found to be 28·6 cubic metres a second. The river was only about 5 or 10 centimetres above it lowest low-stage level as shown by algæ on the stones,

(1) Estimated.



No. 12.—Evaporation Tankwa.

while there were signs of its having been about 30 centimetres higher from local rains. The discharge at Roseires at this time was about 880 cubic metres a second and the contrast with the amount passing Kutai shows the importance of the contributions entering between the two places. Among the most important tributaries on this reach are the Dura, the Didessa and the Yabus or Dabus. Very little is known about these rivers. Mr. Jessen of the MacMillan expedition has described their confluences, but he only saw them in the dry season when their volumes can be very little criterion of their importance during the rainy season. The only way in which the influence of these tributaries can be estimated will be by establishing camps and maintaining observers at their mouths during a flood season. Their valleys are almost certainly steep and they are unlikely to offer any suitable reservoir sites.

Though there had been a few showers early in March, the ground at Bahrdar Giorgis was dry on May 24 and the grass had not yet begun to sprout. At Alafa on the edge of the plateau on May 27, the new grass was already about 30 centimetres high and there were plenty of indications of recent rain. This crop of fresh grass indicates that there must have been a good deal more rain along the outer edge of the escarpment than in the region farther east. These observations suggest that the rainfall is heavier along the western parts of the highland such as those drained by the Didessa and Yabus. This is to be expected, since the moisture-laden winds from the south-west must drop large amounts of moisture on the western slopes of the plateau.

The Run-off.

The observations during 1920–1921 enable fairly definite figures to be given for the amount of water supplied by the catchment of Lake Tana. The size of this, excluding the area of the lake as shown in Chapter II, is 13,750 square kilometres and this supplied about 3,500 millions of cubic metres or the equivalent 254 millimetres over the whole catchment. The rain is certainly uneven over the catchment, but Bahrdar Giorgis, where a rainfall of 1,290 millimetres was measured, is fairly central. If this represents the average, the proportion of the run-off is about 20 per cent. It is of interest to compare this with the run-off of the whole Blue Nile catchment. Apart from uncertainties as to the geographical extent of the Blue Nile basin, the estimate is affected by large areas of soil plains flanking the courses of the river and its tributaries in the Sudan, where the rainfall is completely absorbed. The areas on Map I have been outlined with due regard to the extent of these plains and can be regarded as representing the effective catchments of the various rivers. The areas measured from a larger scale map are as follows :—

	Square Kilometres.
Effective catchment of Rahad	8,220
,, ,, of Dinder	16,020
,, ,, of Blue Nile, excluding Rahad and Dinder areas	193,380
Total effective catchment of Blue Nile	217,620

As a result of the rains in 1920, the Blue Nile discharged 47,000 millions of cubic metres or 216 millimetres from the total catchment. If the average rainfall over the basin was 1,200 millimetres, as suggested by the latest data of the Physical Department, this represents a run-off of 18 per cent. The volumes discharged by the Rahad and Dinder were not

measured in 1920, but assuming that they were proportional to those of 1922 further results are obtained and can be tabulated as follows :—

	Volume discharged. Millions of Cubic Metres.	Depth of Run-off.	Rainfall.	Percentage Run-off.
		Millimetres.	Millimetres.	
Rahad	1,080	130	1,000	13
Dinder	1,970	123	1,100	11
Blue Nile, excluding Rahad and Dinder	43,950	227	1,200	19
Lake Tana	3,500	254	1,290	20

The traverse from Addis Abbaba to Lake Tana, the journeys to Debra Markos, Lebbo, and Delgi, and the return by Alafa to Roseires, enabled much of the catchment of the Blue Nile to be seen. The observations suggest that a great proportion of the run-off is due to rainfall on steep slopes, either of the valley sides, or mountains rising above the general level of the plain. The plateau includes large areas of level or gently undulating country where a large proportion of the rain either forms pools and marshes or is retained by the soil until it is transpired by the vegetation. Photograph 10 showing a flat-floored valley near Dembetcha illustrates an example of much of the country on the Abyssinian plateau. Land on slopes is selected for cultivation and the lower limit on valley sides is formed by the floor, which becomes sodden and swampy and usually bears characteristic sedge vegetation. *Arrami* is an Agau word applied to the swampy uncultivable ground and in Shoa similar land is termed *haro*. The ploughed sloping ground is known as *korapta*. At the beginning of the rainy season the soil is dry and cracked, so that a considerable proportion of the rain is absorbed at once. Later on, the grass grows, often attaining heights of over two metres, and evidently requires a great deal of moisture as well as hindering drainage if there is a slope. The grass and herbage are illustrated by Photographs 3 and 4.

It appears that a shower must exceed about 10 millimetres in amount before any run-off can occur. Amounts less than this are taken up by wetting the surface and vegetation. The quantity required to produce run-off is not always the same, since a less proportion is absorbed when the intervals between showers are short. Where there is dense vegetation or high grass a good deal of rainfall never even reaches the ground. The influence of cultivation on the run-off is probably small, but at first a great deal of water must be held by the ploughed land. The proportion of water which reaches the streams depends on how the rain falls, and it is clear that a few heavy showers may swell the rivers more than the same quantity of rain distributed over a longer period.

The rainy period from October 9 to 18 has been described in the earlier part of the chapter, and it was noted that in spite of the rain there was no appreciable check in the fall of water level in the lake. It seems most likely that the ground and vegetation had dried during the fine days of the early part of the month, with the result that the subsequent rain was absorbed without producing any run-off to increase the streams feeding the lake.

In the descriptions of the routes, Appendix III, some places are noted where there are small lakes with no outlets. The Guderabar lake south-east of Sakala is the largest observed. Kurti Bar is marked as a lake with an area of several square kilometres and is stated by the people of Rim to be a grassy swamp. All these represent areas that

contribute nothing to the streams. Perhaps the best known instance in Abyssinia is Lake Ashangi situated on the eastern edge of the plateau in about latitude 12° 35′ north, and sometimes incorrectly shown with a stream running westwards from it. It was described by W. T. Blanford, (1) who records as a result of careful examination that it has no outlet. The lowest part of the rim by which it is surrounded rises to nearly 50 metres above the level of the water. The lake is about 5 kilometres wide and 6·5 kilometres long. It was estimated that the lake drained the country for a radius of 8 kilometres or a total area of about 200 square kilometres. Blanford assumed that the rainfall was about 2,000 millimetres and this is almost certainly too high a figure. He concluded that the lake must have a subterranean outlet to account for the disposal of all the inflow and because of the perfect freshness of the water. Were the equilibrium maintained by evaporation alone, the water would be saline. Later observations permit other figures to be applied to the problem of Lake Ashangi. A rainfall of 1,200 millimetres with a run-off of 20 per cent on the catchment would contribute 48 millions of cubic metres to the lake. The area is about 30 square kilometres, so that the rain on the catchment would raise the level of the lake by 160 centimetres, to which must be added the amount of rain falling directly on the lake, making a total of 280 centimetres. This agrees fairly well with Blanford's statement that there was no evidence of the lake having risen more than about 3·5 metres above its lowest level. Evaporation losses are probably not very different from those at Lake Tana, consequently it is assumed that 140 centimetres depth of water is carried away by the air. This leaves 140 centimetres to be accounted for by the imperfection of our data, and certainly to some extent by seepage, which must occur, as Blanford argued, to maintain the freshness of the water. In any case it is clear that around Lake Ashangi there is an area contributing relatively little to the neighbouring streams. These facts all emphasize the need for the greatest caution in basing estimates on assumed proportions of run-off, perhaps with inadequate rainfall data. It has been pointed out(2) that such figures are occasionally promulgated with a confidence for which there is no adequate foundation.

There are three conditions of Abyssinia to be considered :—

(*a*) The original condition, such as must have prevailed in prehistoric times, when the country was pathless and fully clothed with vegetation. There were no grass fires during the dry seasons, there was far less grass than now, and the country may have been entirely covered with forest. Under such conditions there was probably less run-off and far less silt was carried away in the absence of defined tracks.

(*b*) The present condition, under primitive human occupation, when annual burning of grass, demands for timber, and clearance for cultivation, have resulted in a large decrease in the forest areas. The grass is kept down to some extent by cattle, but grows almost unrestrictedly over large areas from which the run-off must be considerably reduced. Man has a marked influence on the run-off and the proportion of silt carried into the river. The tracks along which he walks and drives his beasts of burden are followed by drainage and the water picks up the loosened and puddled mud. Many of the slopes are cultivated and on the whole there is probably rather more run-off with more silt than under the original conditions.

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(1) "Geology and Zoology of Abyssinia," London, 1870, pp. 157–160.

(2) Davis and Wilson, "Irrigation Engineering," 7th edition, New York, 1919. p. 40.

(c) When Abyssinia is fully developed, cultivation will extend, marshes will be drained, and there will be a more rapid and larger run-off during the rainy season. The Nile flood will be larger, but there will be less tendency for the ground to be saturated and there will be smaller supplies available during the dry season. Already plenty of water is diverted from small streams for cultivation in the dry season, and it is obvious that more water will be taken as the country progresses. It happens that the river below Lake Tana flows in a deep, well defined valley through a considerable part of its course to the Sudan boundary, so that the waters of Lake Tana never will be of any value to Abyssinia for cultivation during the dry season. The size of the tributaries flowing into the lake during the dry season however will be affected, but this will be balanced by an increased run-off during the rains owing to drainage.

The steep mountain and valley slopes which now contribute a large proportion of the Nile flood must continue in much the same condition.

Evaporation from Pools.

The country around the Tana Mission camp became thoroughly sodden during the rains. In all low lying places there were pools with high grass and it was hardly possible to go more than 200 metres in any direction from the tents without having to wade. Yet experience has shown that the site was as good as any for a camp. Towards the end of the rains observations were taken to record the rate at which the pools dried up. There were occasional showers which raised the water levels, but the observations are displayed on Diagram 3, which shows that the pools dried at very even rates of about 10 millimetres a day and the rate increased as the areas diminished.

Seiches.

The existence of a seiche on Lake Tana was first observed by Mr. Buckley during 1916. The total variation of the seiche is much smaller in the dry season than during the rains, when it may attain to about 18 or 20 centimetres. The period of the seiche is irregular but is generally from three to four hours. It may be due to various causes such as wind, variation in the discharge of inflowing streams or storms and heavy rainfall on part of the lake, disturbing the waters. The wind of the dry season did not cause any appreciable seiche, even though it was strong and altered its direction daily, blowing first from south-east and later from the north. The seiche became marked after storms of rain and a heavy fall on a part of the lake appears to be the most likely cause. Sudden increases in the discharges of streams do not seem capable of causing the effect observed. The increases would occur relatively gradually and die away as gradually afterwards. Moreover, any increase in streams that rise quickly can only have a very small effect on the level of the lake at their mouths.

On several occasions gauge readings were taken continuously every ten minutes during the complete period of a seiche, and particularly on October 8, when simultaneous observations of water level were taken at three different points on the lake and two on the river.

These points were :—

(1) Fig Tree.

(2) Northern end of Debra Mariam Island.

(3) Southern end of Debra Mariam Lagoon just upstream of Chara Chara.

(4) Kamforo Ferry.

(5) Burifasas Discharge Site.

An examination of Diagram 5, showing all five sets of observations, shows that there is no appreciable lag between any two of the three points on the lake and hence that the Fig Tree gauge is representative of the lake outlet.

We can therefore proceed to compare the phase at any point on the lake near the outlet with that on the river. The observations may be tabulated as follows :—

	Time of Minimum.	Difference.	Time of Maximum.	Difference.	Time of Minimum.	Difference.
		Minutes.		Minutes.		Minutes.
Lake	—	—	10·25	55	12·25	40
Kamforo Ferry...	09·50	30	11·20	45	13·05	25
Burifasas	10·20		12·05		13·30	

On an average there was an interval of 47 minutes between the corresponding phases at the Lake and Kamforo Ferry and 33 minutes between the Ferry and Burifasas. The distances from Chara Chara are 2 kilometres and 6 kilometres respectively to Kamforo and Burifasas and are in remarkable contrast to the intervals in the phase. Any explanation must accord with the fact that floats released at the Ferry reached Burifasas in about 1 hour and 40 minutes. Unfortunately none of the floats released at Chara Chara reached Kamforo, but experiences with *tankwas* on the rapid current of this part of the river suggest that they would have been carried down in 15 or 20 minutes. When the very irregular nature of the channel below Kamforo is considered the apparent anomaly in the difference of phase is fairly simply explained. There is a cataract immediately downstream of Burifasas, consequently the water level depends directly on the volume passing over the sill. The river level at Kamforo Ferry depends on the discharge and also on the slope, which varies and requires some time to attain equilibrium when the discharge alters. The channel downstream of the Ferry opens out and is wide for some distance. Moroever, it is flanked by some extensive papyrus swamps and the whole extent of these must be filled up by any increase in the discharge before equilibrium is established and the Ferry gauge attains its normal reading corresponding to the discharge. At the same time, while the section is filling, the discharge at Burifasas increases and the river attains its maximum level almost as soon as the channel is full. An increase in the discharge from the Lake causes, to begin with, an increase of slope at the Ferry and this gradually diminishes as the sections down stream fill up. The effect of the increase in slope is replaced by an increase in the size of the section as the channel fills up and equilibrium is attained. Such an explanation is in accord with the time taken by the floats, for these would travel more slowly than the level effect through the wide sections. The gauges reach their highest levels when the filling of the section has been completed, but the water passing out of the lower end, even when equilibrium has been established, was already in the channel when the change in the discharge occurred. The sections upstream of a cataract may be com-

pared with the channels upstream of weirs and dams, where water levels are controlled through some range at the obstruction. The records are of interest in showing the extent to which the seiche effect is damped, even in its passage along this short reach of the river. They also bear on the application of Kutter's formula for finding discharges. The seiche causes a continuous variation of slope which alone would vitiate the accuracy of any formula involving slope measurements. The irregularity of the river section and the swamping alongside it in the reach below the outlet are shown in Map III and Photograph 14 and their effects on the flow are well demonstrated by the retardation in the phase of the seiche.

Diagram 4 is based on observations at 10 minute intervals and shows the variation of level on several days when there were seiches. Diagram 9 depends for the most part on isolated observations of the water levels. The maxima and minima have been inserted for the times when the levels were followed in detail and it is clear that the irregularities in the other parts of the trace are due to the joining of odd points on what should be a record of continuous vibrations. Realizing this, and as detailed in Chapter V, instructions were given that the gauges should be read as frequently as possible whenever any of the staff happened to be in their neighbourhoods. The diagram shows that the surface of the lake was steadier from November until the end of February, when it became disturbed, coinciding with the onset of stormy weather.

ESTIMATED INFLUX INTO LAKE TANA

Diagram Nº1.

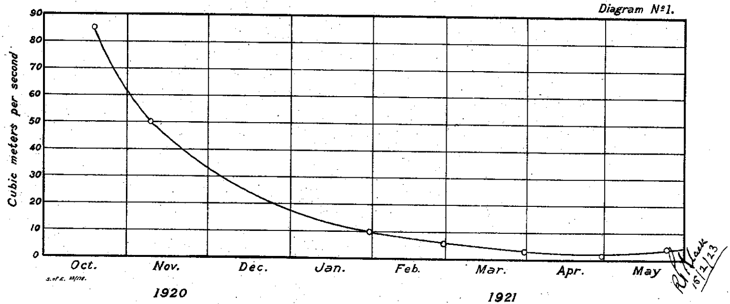


Chart showing meteorological observations

at Bahrdar Giorgis

August 1920 – July 1921.

Diagram No. 2.

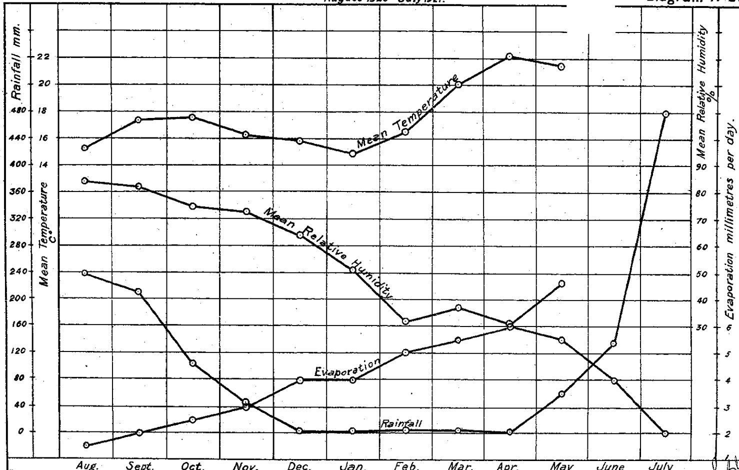
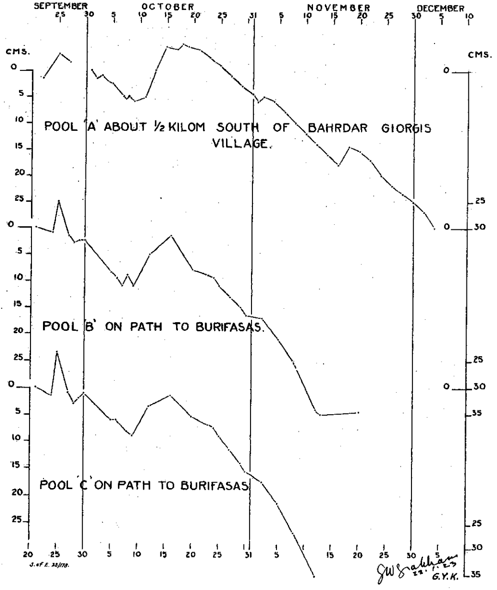
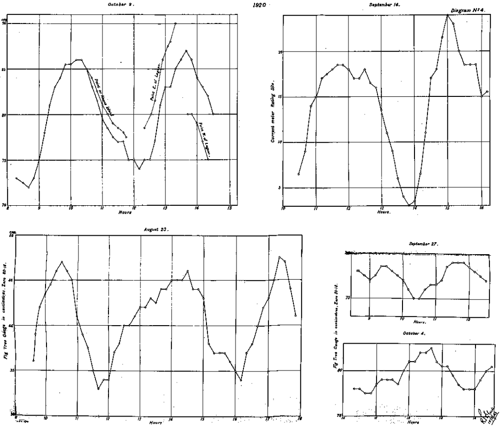


DIAGRAM 3.

EVAPORATION FROM POOLS.



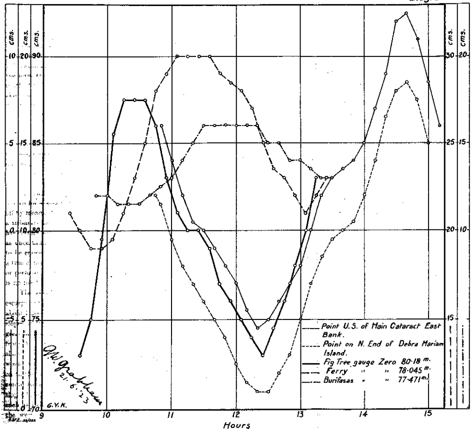
TYPICAL SEICHES
1920



SEICHE OF OCTOBER 8th 1920

LAKE AND RIVER LEVELS

Diagram No 5.



CHAPTER IV.—GEOLOGY AND PHYSIOGRAPHY.

Position of Lake Tana.

The Abyssinians distinguish types of country according to the altitude. The *Kolla* is low land between sea level and about 1,800 metres; the *Woina Dega* or wine highland is between 1,800 and 2,400 metres and includes the great proportion of the plateau, while the term *Dega* is land about 2,400 metres, and applies to Semyen and parts of Gojam south of Lake Tana. The surface of Lake Tana stands at an altitude of about 1,840 metres above sea level, and though the immediate neighbourhood is regarded as *Woina Dega* it is relatively low, and is not looked on with favour by dwellers on the higher lands around. Until recently the western edge of the Abyssinian plateau was not well defined, and inspection of the published maps might have conveyed the idea that the lake lay in a central depression in the middle portion of the Abyssinian highlands. The position of the escarpment forming the western edge of the plateau in the region near Lake Tana is now better defined, mainly as a result of route surveys, and it proves to be situated within a few kilometres distance throughout almost the whole length of the western shore. This is shown on Map II and Section 6, but in compiling the map the position of the watershed near Delgi was shifted too far west and unfortunately this was not noticed until the plate had been prepared. The proximity of the watershed at the north-western corner has been known for a long time, and Mr. Dupuis(1) noted that the waters of the lake could be drawn off by means of a tunnel 13 or 14 kilometres long opening into the ravines of the Jira river, a tributary of the Rahad. Though he states that such a project is perfectly feasible and has certain advantages from the purely technical point of view, he regarded the advantages as uncertain, the political difficulties as probably insurmountable, and the cost as likely to be enormous. The recent surveys indicate that there may be a rather shorter line for a tunnel near Gabgabit where the water might debouch into the head waters of the Dinder or perhaps the Balas. The disadvantages of such projects seem to be so great that there is no need to discuss them further at present.

The western shore slopes up to a height of about 2,300 metres along the edge of the escarpment, only a few kilometres distant from the lake. Below the escarpment, at about 1,200 metres level, are plains which slope gently down to the Sudan. The tremendous slopes of the escarpment, shown in Photograph 34, have been thought to be due to some great fault or dislocation of the earth's crust. Careful scrutiny in the course of the descent from Alafa has failed to reveal anything of the nature of a fault. All the indications show that the escarpment is a result of simple processes of erosion. It is not straight as would be a fracture, but is fringed by a number of spurs and ridges, which stretch westwards on to the plain. Not only is such topography typical of ordinary erosion, but the horizontal basalt sheets of which the spurs are built up can be traced to the foot of the higher slopes behind. There is no trace of a dislocation, and it is clear that the spurs and outliers, such as Belaiya and Kwara, are relics of the plateau having extended much farther to the west.

(1) "Report on the Basin of the Upper Nile," London, 1904, p. 226, also Plan XIII. The scale of this plan is marked as 1: 5,000, but it should be 1 : 50,000.

On the north, the divide separating the catchment of the lake from that of the Atbara does not rise to any considerable height. The shore is broken by the rocky Gorgora peninsula, separating two stretches of low marshes. East of the Gorgora Hills is the Dembia plain, which is alluvial, and has been laid down by the Magach, Dirma and other rivers. North-east of this plain rise the mountains of the Dankaz-Lebbo ridge, attaining heights of nearly 4,000 metres above sea level, and forming the divide between Lake Tana and the Setit or Takkazye. The north-east corner of the lake washes up against the foot-hills of this range, and south of them are the Fogara plains about 300 square kilometres in extent, filling a great bay in the hills, and traversed by the Reb and Gumara rivers, which have brought down alluvial deposits to form them. The hills east of the Fogara plains rise to considerable heights, and the drainage feeds the two rivers. The high land continues southwards, and the Blue Nile flowing from Lake Tana passes along a deep, well defined valley. The Amedamit Mountains south of the lake attain heights of about 4,000 metres and their western slopes fall towards the Little Abbai, which drains an open valley between them and the hills on the edge of the escarpment to the west. This stream is the largest tributary and enters at the south-west corner with a long deltaic arm reaching far out into the lake. South of the basin of the Little Abbai the level of the plateau falls and it appears that the escarpment is relatively low in the Damot country west of Gojam.

The shore of the lake is fringed by numerous small islands, while the larger inhabited islands of Dek and Dega are situated towards the south-west side. Dek has a flat outline rising very little above water level, while Dega, the smaller island to the south-west, is marked by a small prominent hill. Many of the small islands near the shores bear churches or monasteries.

The shores of the lake are usually low and it is flanked by the two great alluvial plains already mentioned. These plains were carefully surveyed by the late Col. H. D. Pearson, R.E., and Mr. A. B. Buckley, and we are indebted to the latter for the following information about them. The level 81·30 metres was adopted as representing the high-water line throughout these surveys and the results have been, as far as possible, included in Map II, while they have been published more fully in the 1 : 250,000 scale maps of the Sudan Survey Department.

The Fogara plain is the most important area of its kind on the borders of the lake and it has an area of about 300 square kilometres. At its northern end the plain narrows to a point. At its southern end, the lake, during the flood season, stretches as much as seven and a half kilometres inland of the low-water line, while, at the northern end, at the village of Grigna, the level of the ground is above high water level at the foot of the hills two kilometres from the shore. Mr. Buckley states that the edge of the lake at low water varies in character. In the proximity of rivers and various spill channels the level of the ground is usually high, being only 30 centimetres below flood level or even slightly above it; such spots are covered with short, close growing grass. The levels fall away as the distance from the channels increases, the slope becoming very flat and the ground swampy and fringed with sedges which grow to heights of about two metres. There is no papyrus along the shore of the Fogara plain. At the mouths of the rivers there is some basalt sand. The soil is usually of a dark brown colour and samples supplied by Mr. Buckley to Mr. A. Lucas, late Director of the Government Analytical Laboratories, Cairo, were proved to make excellent *homra* when burnt. A curious feature of this plain, observed by Mr. Buckley, is a long ridge running parallel to the water's edge with its base on the River Reb, and



No. 13.—Northern Shore of the Lake.

extending southwards from the river. It varies in width up to 150 metres and in places attains a height of a metre above flood level. The highest points are occupied by huts, pepper cultivation, and other domestic crops, while on the slopes, from the top right down to the water's edge, are sown wheat, *durra* and similar crops. He explained the formation of the ridge as being due to wave action. It is in many respects similar to the low sandy banks found elsewhere on the lake shore near the flood limit, but this one is peculiar in rising from the shore some 1,200 metres on the lake side of that line.

The outer edge of the plain is dotted over with huts in positions just above flood levels. Farther inland, the dwellings and cultivations occur on the berms of the rivers traversing the plains. It seems likely that the people only come to the shore from December to the beginning of June to give their cattle the benefit of the pastures at that season. An important cattle grazing area lies between the lines of high and low water. The grass consists of coarse stems which float when the water is high enough, making a treacherous surface which, although solid in appearance, may, as Mr. Buckley observed, cover a depth of water of anything up to half a metre, in which the cattle stand and graze. As the water falls the grass settles, but its thickness is such that it never forms a solid surface. Above high flood level, Mr. Buckley remarked that the land was covered with ordinary grass growing to a height of about 160 centimetres. In the neighbourhood of the high flood level the grass is rather lower. The plain near the lake shore is remarkably free from swamps, and Mr. Buckley only records them as existing between the Gumara river and the Gugubi Hills and in the angle formed by the left bank of the Reb and the long ridge already mentioned. These swamps were often swarming with mosquitoes, but it appeared that they only attacked people wading in the swamps, while camps at a little distance were not molested.

As regards churches, Mr. Buckley only found two important ones in the neighbourhood of flood level, namely Markarios and Navaga. Owing to restrictions imposed on survey work, the levels could not be ascertained, but they are certainly not less than one metre above flood level and probably much more. Both churches were surrounded by thick clumps of trees covering areas amounting to about twenty acres.

Patches of cultivation were met with at intervals along the edge of the plain, the crops having been sown as the water receded, but the table below shows that the area of cultivation is very small.

The Dembia plain forms the eastern part of the northern shore of Lake Tana. Mr. Buckley found that it has an area of about 300 square kilometres and borders the lake for a distance of twenty-two kilometres from Bula Gratch near Ambo on the east to the Gorgora peninsula on the west. Near Bula Gratch the foreshore is not more than 300 metres wide, and during flood the water comes to the foot of *talh* wooded hills. West of this the character of the shore changes, the hills recede from the water's edge, the *talh* forest continues two kilometres farther to a promontory and from there recedes inland; from this point the forest ceases and only an isolated tree is met with at intervals. The water's edge at 80·40 metres near the path along the shore in this neighbourhood is shown in Photograph 13. This illustrates the swamp vegetation in the foreground, and in the distance, across the water in a south-easterly direction, are the foot-hills of the Lebbo range. Mr. Buckley found that the flood line nowhere recedes very far and that, 5 kilometres west of Bula Gratch, the strip of foreshore at low water is only about 100 metres wide. A few collections of huts hardly worthy of the name of villages lie along the edge of the plain. From Kidan Imra point the flood line recedes, leaving a maximum width of foreshore

of about 1,000 metres at low water, and then closes in to the lake at another spit of land evidently formed by the branch of the lesser Gumara river, the main estuary of which lies 3·5 kilometres farther west by the village of Liglig, whose inhabitants give the stream the name of Sinsel. East of this village Mr. Buckley saw three small plots of barley cultivation. West of Liglig the flood line turns north and the foreshore expands at low water to a width of 1,700 metres and this extends two kilometres west of the village, where there is a ridge with a collection of huts on its point. The parish of Achara Mariam stretches west from this, and here the most important amounts of cultivation occur, but Mr. Buckley found that they end at flood level, though in places the areas may be under water for a width of 200 metres when the lake is at its highest. The next feature is the promontory formed by the mouth of the River Magach which flows into the lake on its western side. Achara Mariam church lies four and a half kilometres to the north and slightly to the west of this point, and the level of the land in its neighbourhood proved to be about 82·75 and consequently the floor of the church must be higher. In fact it is obviously well above the flood level.

Between the mouth of the Magach and the Dirma there is a shallow bay seven and a half kilometres wide and beyond it the plain ends against the Gorgora Hills. Along this bay the foreshore at low water was found by Mr. Buckley to have an average width of some 1,500 metres, although towards the Dirma river it may amount to as much as two kilometres. The foreshore narrows and the land rises to form banks in the immediate neighbourhood of the Dirma river. Between it and the Magach Mr. Buckley was able to trace several old channels, probably marking the former courses of the Dirma, which must have burst its banks and made itself the new channel where it now flows. Col. Pearson's and Mr. Buckley's surveys showed that the line of the foreshore of this plain varies considerably from that given on Stecker's map, where three prominent spits are shown jutting out into the lake.

Between Gorgora peninsula and the village of Delgi there is a bay about 8 kilometres wide in the high land partly filled by a low plain. At the Gorgora side, the foreshore is about 1,200 metres wide at low stage water level and this strip becomes smaller towards the west, and the higher wooded slopes approach close to the water where the Serwaha stream flows into the lake. From this point to Delgi the lines of high and low water are never more than 500 metres apart.

The following list, due to Mr. Buckley, gives the areas of foreshore exposed during low water level, assuming 81·30 represents flood level.

Cultivated Areas liable to Flooding around Lake Tana.

	Area of foreshore between the 81·30 and 79·30 contours.	Area of foreshore under cultivation at the time of the survey in 1916.	Areas of ploughed land on the foreshore.	Areas of foreshore showing signs of having been cultivated in former times.
	Feddâns.	Feddâns.	Feddâns.	Feddâns.
Fogara Plain ...	14,300	267	16	445
Achara Plain ...	6,059	194	—	—
Delgi Plain	2,460	—	—	—

From the above it appears that the areas under cultivation were insignificant. Mr. Buckley was unable to extend his surveys of the foreshore to the Abbai plains or the Island of Dek.

Geological Formations.

The formations met with in Abyssinia in ascending order of age are as follows :—

(7) Alluvium and soils.
(6) Recent Volcanic formations.
(5) Aden Volcanic Series.
(4) Plateau Basalts.
 Upper Series.
 Lower Series.
(3) Antalo Limestones.
(2) Adigrat and Nubian Sandstones.
(1) Metamorphic Rocks.

This list is essentially that given by Blanford (1) in 1870. Since that date, much has been written about the geology of Abyssinia and among modern writers is Carl Rathjens, (2) who gives a general description and appends a valuable bibliography. A geological map was published by Dainelli and Marinelli in 1908 (3) and the general relationships of the region have been dealt with by Suess (4) and by Professor J. W. Gregory. (5) It is to be regretted that circumstances have rendered it impossible to give full details of the most recent writings dealing with the geology of the neighbourhood of Lake Tana, consequently the present account is only to be regarded as a general description of the rocks met with in the course of the Mission. The distribution of the formations is shown in the Geological Section, Section 6.

The Metamorphic Rocks.

These were met with at and west of Khor Abu Gemeiz on the road from Dunkur to Roseires. They include various types of gneisses as well as beds of crystalline limestone or marble and have been penetrated by granites and syenites. The rocks are banded and the general direction of the strike of the banding is north and south or north-west and south-east. A number of beds of crystalline limestone and dolomite occur between Khor Abu Gemeiz and Abba Mendi and will be very important sources of lime when this region is developed. They are too remote to be of any practical interest at present.

The Adigrat Sandstones.

There can be no doubt that the sandstone met with in the Blue Nile valley at Kutai is the same formation as the Adigrat Sandstone described by Blanford. It proved to be identical in appearance with the Nubian Sandstone of the Sudan and this strongly supports Rathjens' suggestion that one is a continuation of the other, both being of the same age. The base of the sandstone was not seen at Kutai but rocks of the same type are seen resting on the metamorphic rocks at Khor Abu Gemeiz. They are white or buff coloured sandstones with intercalated beds of grey or purple mudstones or even clays. This series forms

(1) *Loc. cit.*
(2) Mitt. Geog. Gesellschaft, München, pp. 222–310, Sept. 1911.
(3) *See also* "Carta Geologica della Regione Etiopica," Rev. Geog. Italiana, 1909, pp. 377–387.
(4) "La Face de la Terre," translated with notes by Emm. de Margerie, Vol. III, Pt. 3, pp. 974–977, with map. Paris. 1913.
(5) "The Rift Valleys and Geology of East Africa," London, 1921. This also contains a comprehensive bibliography.

a belt between the metamorphic rocks and the basalts in the region of Gedaref and Gallabat and almost certainly extends continuously southwards to the neighbourhood of Dunkur and beyond. Blanford did not find any fossils in the Adigrat Sandstones, while, in the Sudan, apart from plant remains, no fossils have been found that permit the age of the formation to be determined.

The Antalo Limestones.

These were shown by Blanford to be of middle Jurassic age and Gregory (¹) reviewing more recent investigations concludes that it is more convenient to subdivide the limestone, restricting the term Antalo Limestone to the lower division, which is mainly or entirely Bathonian, and adopting Aubry's name of the Lagagima Limestone for the upper beds corresponding to Kimmeridgian and Corallian. The Antalo Limestones rest on the Adigrat Sandstones, which must therefore be older. Beds belonging to some part of the limestone series were met with below the basalts and resting on the sandstone on the south side of the Blue Nile valley at Kutai and proved to be formed of brown or light grey saccharoidal limestone full of small fragments of organic remains such as parts of shells of bivalves. The bed was about 60 metres thick at the Urgan pass, and since both it and the sandstone below are horizontally bedded, the one seems to rest conformably on the other. There is a small proportion of limestone pebbles in the shingle of the bed of the Blue Nile, showing that these beds occur farther up the valley, and the rock represented is usually a light grey or a cream coloured compact limestone. The limestone bed does not appear to occur on the northern side of the valley at Gimam, where the basalts rest directly on the sandstone. It either thins out towards the west or it was all eroded away before the basalts were erupted. On the north-east, in the region particularly described by Blanford, it is a persistent formation occurring between the sandstone and the basalt. The sedimentary formations met with on the Jibouti railway near Dirre Dawa and between this place and the coast have been given the same colour on the geological section as the Antalo Limestone. The exposures nearer the coast are of sandstone associated with limestones and shales, while those near Dirre Dawa are of limestone, but there was no opportunity for close examination and they may prove to be quite different formations.

The Plateau Basalts.

These form a horizontally bedded series which was found to be thickest towards the west. Here, from the base of the basalts west of the escarpment to the surface of the plateau, they attain a thickness of 1,600 metres on the paths actually traversed. Some distance farther east the almost horizontally bedded series forms the Amedamit Mountains, attaining a height of nearly 4,000 metres above sea level. The bedded lavas can be regarded as forming a consecutive series certainly over 3,000 metres in thickness, but it seems unlikely that the whole of this great pile is represented in any one place. The unevenness of the base of the basalts is shown by the various heights at which it is met with. On the west near Khor Damu (Dunkur) it stands at about 600 metres above sea level, 1,850 metres at Gimam on the north side of the Blue Nile valley, about 2,000 metres at Ereisa Sardo opposite, and over 2,000 metres at the Urgan pass. The base of the bedded basalts appears there-

(¹) *Loc. cit.*, p. 338.

fore to slope gently down from east to west, and since the beds seem to be horizontal, it is suggested that these differences of level represent the slopes of the sandstone surface over which the lava sheets were erupted.

The abruptness with which this great series terminates on the west is remarkable. The agents of denudation have modified the original outlines and carried away vast quantities of rock, but the outlying masses of Kwara and Belaiya show that the basalt series formerly stretched westwards, probably to a point even farther, with almost the same thickness as at the edge of the modern escarpment. Yet, only 50 kilometres beyond these outliers, the basalt ends and sandstone and metamorphic rocks occur without any trace of their ever having been covered by volcanic rocks. No dykes or intrusions were seen traversing them. It is evident that the foci from which the great sheets of lava flowed out were situated towards the east, and the floor below the western edge of the lavas was far from any centre of dislocation or eruption. The sandstones met with in the Blue Nile valley also appeared to be free from basalt dykes, and it seems likely that the eruptions occurred in definite centres, one of which may be where stand the Amedamit and Choke Mountains, while the underlying rocks at a distance were hardly at all disturbed or invaded by intrusions of the molten rock.

Blanford (1) distinguished two series, namely the Ashangi Group below, and often inclined, and the Magdala Group, which is horizontally bedded and rests with marked unconformity on the upturned and denuded edges of the lower group. He records that the Ashangi Group is composed of doleritic rocks usually amygdaloidal, containing nodules of agate and zeolites, while the basalts of the Madgala Group are more compact, being associated with trachytic beds and in places contain interstratified sedimentary rocks. Prof. Gregory suggests that the Ashangi traps correspond with the Kapitian of East Africa, while the Magdala traps are the equivalents of the Laikipian and Naivashan series.

Lower Series.—Observations in the course of the Tana Mission have not led to the recognition of a lower group of traps separated from an upper one by a marked discordance, but descending the escarpment of Alafa, the basalts at the base of the escarpment proved to be characterized by abundance of agates and zeolites, including stilbite and fibrous aggregates of the thompsonite group, all frequently associated with green earths. Beds exhibiting these features extend to the western limit of the bedded basalts near Dunkur and occur also at Gallabat, where they must represent a similar position in the series. The late Mr. T. Barron recorded a break in the series as occurring at Wahni on the Gallabat—Chilga road, and this would correspond closely in position as regards the summit of the escarpment with the point at which the lower group was found below Alafa. It seems likely that the horizontally bedded lower group is the equivalent of Blanford's Ashangi Group, which, however, has been tilted where he observed it, in the north-east region of Abyssinia. The agates and zeolites are far more resistant to weathering than the basalt which contains them and the consequence is that, while the basalt decomposes readily, they remain strewn on the surface of the ground and are quite a feature along the path west of the escarpment.

The lower group of lavas is met with up to about 1,400 metres above sea level, consequently they must have a thickness of at least 700 metres. Exposures of the surfaces are generally poor, but the available evidence points to subaerial origin of these basalts.

(1) *Loc. cit.*, p. 182.

There are beds of scoria interstratified with them, the surfaces are often highly amygdaloidal and at J. Luban in the Sudan, remains of fossil wood are associated with them. The rocks are typically olivine dolerites, often with a little analcime in the ground mass.

The Upper Series of lavas forms the greater part of the face of the western escarpment and the surface of the plateau as well as the mountains of Amedamit and Choke. In the Lebbo range there is a bed of trachyte more than 300 metres thick which appears to lie horizontally with the basalts. Between Sakala and Injabara, masses of trachyte were met with forming conspicuous cone-shaped peaks such as Adsum Sillasi and that of Injabara itself. The relationships of these trachytes to the bedded basalts have not been determined, but that of Lebbo is conformable, while the masses near Injabara may be either parts of a thick flow or separate bosses. Rhyolites occur and seem to be associated with the upper group of basalts. This type of rock forms the river bed at the cataract of Faras Egr about 10 kilometres below the outlet of Lake Tana, and specimens were collected by M. M. Kherbeguian from Amba Sel near the eastern side of the plateau in the course of his journey to the lake. Thus the upper group, and its association of basalts with trachytes, resembles the Magdala Group of traps defined by Blanford. It appears to be much thicker than the lower group, extending from its base about 1,400 metres above sea level to the highest parts of the plateau at about 4,000 metres altitude, suggesting a thickness of 2,600 metres.

In the course of the descent over the escarpment at Alafa it was seen that various basalt beds could be readily distinguished by their petrographical characters, one being coarse grained, another fine grained with or without phenocrysts, and this variation of type was borne out by observations elsewhere, but it must remain for some future generation to map out the limits of the individual flows. Among the basalts, the petrological types range from rocks composed almost entirely of felspar, augite and iron ore, with a little interstitial analcime, to varieties with augite, olivine and felspathoid minerals, but only small proportions of felspar. The trachytes appear to be normal rocks composed of alkali felspar with a small proportion of pleochroic green augite, while the rhyolites are either glassy or cryptocrystalline with flow structures and perlitic cracks and sometimes forming fluxion breccias with inclusions of previously consolidated rhyolite. The plateau basalts occur on the east bank of the Blue Nile at the outlet and are dealt with in the course of the geological description of that region.

Blanford found sedimentary rocks interstratified with the lavas of the upper group and, though no such beds were met with in the course of the Tana Mission, it may be noted that a bed of palagonite tuff with rounded pebbles is associated with the basalts a few kilometres north-east of Debra Markos. The coal-bearing beds of Chilga were found by Mr. Barron to be faulted down among the basalts and seem therefore to be younger in age. It appears that they are lacustrine deposits accumulated in a depression among the basalts, and the quartz sands must have been derived from areas of crystalline rocks, granite or gneiss at higher levels, presumably to the north or north-east. At present we do not know of such masses. At the north-east corner of the lake, in the neighbourhood of Delgi, there are large deposits of quartz sand at the mouths of streams also along the shore and it is suggested that this has all been derived from a continuation of the Chilga beds extending into the Tana catchment area.

The beds of the upper group of Plateau Basalts have, like the lower series, been erupted subaerially and the interbedded sediments mentioned by Blanford are to be regarded as marking intervals when lakes existed in hollows.

The Aden Volcanic Series.

This was regarded by Blanford as including a well defined series of eruptive rocks extending from the Tertiary Period down to quite recent times. Modern authors have limited the series and it is doubtful whether any representatives of the restricted group were met with in the course of the Tana Mission.

Recent Volcanic Formations.

These include the Bahrdar Giorgis lava to which the origin of Lake Tana is due. Their greatest extent in the Abyssinian region is in the Danakil plains, where they cover a stretch of country extending from the Harrar escarpment on the south to the coast as far as Massaua on the north. The railway from Jibouti lies on them, over most of the route to Addis Abbaba. In the Rift Valley west of Hawash Station, there are many quite recent volcanic cones, including Mount Fantale, and the railway traverses a bed of lava with its hummocky and scoriaceous surface free of soil and vegetation and still quite unaltered by weathering. The eruption of this lava flow has resulted in the blocking of drainage lines and the formation of sheets of water that are seen close to the line. Near Addis Abbaba great volcanic cones such as Wachecha to the south-west and Harrer to the south-east, as well as Sekwala, attain heights of over 3,000 metres and form majestic features in the landscape. These with their smooth outlines, and in some cases crater lakes, must be geologically of quite recent origin.

On the route from Addis Abbaba to Lake Tana a recent volcanic formation was met with at the Guderabar lake, which has been formed as a result of a volcanic dam. The lava is highly scoriaceous and its surface has been thrown up into hummocks rising 3 or 4 metres above the general level.

In the neighbourhood of Rim, evidence of recent volcanic action is again met with and extends northwards to the shores of Lake Tana. The existence of this important lake is due to an eruption of lava originating from a point probably north of Rim, whence the flow ran down the slopes northwards, spilling over into the valley of the Little Abbai as well as into that of the Blue Nile, which it partly blocked. Lava covers a great area of country and the question arises as to whether it was not the result of more than one eruption. The route from Bahrdar Giorgis traverses lava of the same type all the way to the ford of the Little Abbai and this suggests that we are dealing with only a single eruption. On the other hand, there are a number of volcanic cones in the vicinity. Most of them have suffered very little erosion, the craters may be breached but are otherwise well preserved. Some of these, as for instance Mikara, have arisen through the plateau basalts, and though it is obviously quite recent, it and the little basalt flow associated with it must be quite distinct from the eruption that produced the Bahrdar Giorgis lava. It is clear that there was a series of eruptions resulting in a number of distinct cones.

The Bahrdar Giorgis lava extends along the shore of the lake most of the way from Zegi to the outlet and down the Blue Nile valley to beyond the first bridge, a distance of nearly 40 kilometres. It has filled up the old valley perhaps to a depth of about 100 metres near the outlet, forming a gently sloping floor extending across the valley and bounded

by the upper parts of the original valley sides, which are composed of the Plateau Basalt series and rise steeply above it. The lava has weathered considerably and a great part of the surface is already covered with red soil. The covering is thin and it is broken here and there by rocky hummocks and ridges similar to those seen on the still more recent lavas west of Hawash and near the Guderabar lake. The hollows are usually covered with tall grass and become waterlogged during the rains, while hummocks and ridges bear trees and bush. The surface of the lava south of Bahrdar Giorgis has a distinct slope to the south-east, which is doubtless the direction of flow, and consequently it has run against the eastern slopes of the original Blue Nile valley. The lowest line along the valley is therefore where the lava abuts against these slopes and the outflow of Lake Tana now finds its way along this course. Before the eruption of this lava the Blue Nile occupied a deep valley in this vicinity and must have been a powerful stream during the rainy season. It then carried the united discharges of the Little Abbai, the Gumara, Reb, and all the other tributaries that now fall into the lake. This certainly amounted to well over 1,000 cubic metres a second, and the water was laden with silt and coarser debris, giving the stream considerable powers of erosion. The lava came and filled the valley, the water had to rise upstream of the lava blockage and when the new lake was full, perhaps after two or three seasons, it spilled out along the lowest line down the valley.

Earlier travellers have referred to the origin of Lake Tana, and Rathjens (¹) in summarizing their accounts mentions that Heuglin regarded it as occupying a huge volcanic crater, Stecker referred to the existence of crystalline rocks in its neighbourhood and this received support from the writings of Dupuis and Tancredi, but, on the other hand, Moratti, a geologist, found only volcanic rocks. Rathjens suggested that the lake resembles Lake Victoria Nyanza in occupying a sunken area. It is clear that none of these travellers recognized the significance of the recent volcanic formations near the outlet or the bearing of their presence on the origin of Lake Tana in the manner described in this chapter. The evidence for the former extension westwards of the plateau has been described and it is as a consequence of the ordinary processes of erosion that the slopes have been worn back until the lake is now in close proximity to the great escarpments immediately west of it. We have suggested that the great basalt plateau of Abyssinia has been built up around centres of eruption which may still be marked by some of the highest mountains. If this is true, the original drainage of the country must have run outwards from these centres to join the main streams, the positions of which were determined by the boundaries of the various piles of lavas. Just as occurs in Gojam, where the minor streams run outwards from the highest points of the Amedamit and Choke Mountains and enter the Blue Nile, which we may suppose pursues its circular course marking the line where the Gojam lavas met those of Bagyemidir and Shoa. In such a manner, the curious course of the river, which has aroused a good deal of speculation, may be fairly simply accounted for without invoking the aid of complex fractures for the existence of which we have no evidence.

The rock of the Bahrdar Giorgis lava is a rather coarsely crystalline olivine basalt, the olivine being distributed through it in streaks and granules. The surface is vesicular and scoriaceous and this character is well displayed among the cataracts at the outlets as well as at many points along the river, where it forms piles of loose spongy looking blocks

(¹) *Loc. cit.*, p. 21.

as shown in Photographs 6, 12, 17 and others. The prevalence of the vesicular type of rock over the surface is due to the original crust of the lava being still preserved. The vesicular type does not extend to a depth of more than two or three metres and below it the rock is compact and jointed, probably into irregular columns, as may be seen during the low stage season on the floor of the Chara Chara cataract. In some places, as at the mouth of the Ifwadda Lagoon, the vesicles occur in layers, giving the rock a stratified appearance and suggestive of movement having occurred in the nearly solid rock. There has also been some mixture of the types, and here and there fragments of the vesicular variety, after they had solidified, have been caught up and enveloped in the compact portions, but examination shows that there is no petrographic distinction between them. Fracture shows that the large vesicular cavities are partly filled with acicular mineral growths, not actual crystals, and these hang vertically from the upper surfaces of the cavities. They are white and tasteless but do not seem to be preserved in the outer crust where the rock is becoming weathered. In pieces of the rock that have been displaced, the hair-like growths are found correspondingly inclined. Besides the vesicles, the rock contains a number of minute interstices which are perhaps more abundant in parts of the compact variety than in the vesicular types. These interstices are only a fraction of a millimetre in diameter, but they are a characteristic feature of the lava and give the broken surface a rough, almost miarolitic appearance. The rock generally presents an extremely rough weathered surface, due not only to the vesicular character but also to the miarolitic parts weathering more readily than other portions. Apart from the vesicular and massive varieties, the texture of the rock is very uniform, though at Egirrbar it is rather coarser grained, with a distinct porphyritic tendency among the felspars. The specific gravity of the compact varieties of the rock was found to be about 2·67, which is rather low for material of this mineral composition and shows that it must contain nearly 10 per cent of interstices. The vesicular parts must be much lighter and should be avoided in selecting building stone for any important structure, though it is perhaps preferable for construction of houses. The jointing of the massive rocks has already been referred to. This is likely to be quite fine and of no importance structurally, but it appears that it affords passage for a small amount of seepage. For this reason some drainage must be provided for any deep excavation into rock near the lake.

The microscope shows that the petrographic character of the rock varies from place to place, but there are certain constant features. It is composed mainly of basic plagioclase felspar, augite and olivine. The augite in samples from near the outlet is granular, while at Egirrbar it builds larger crystals, tending to envelop the felspars, and is ophitic in habit. This mineral in the larger grains is everywhere characterized by its freshness and by a distinct violet tint which is darker towards the margins of the grains, indicating its titaniferous character. In the smaller individuals of the granular varieties this character is either not distinct or is represented by a smoky appearance. The olivine is typically clear and fresh, with a tendency to form porphyritic crystals, especially where the felspar attains larger dimensions. The compass is unreliable on the lava and at points on a line near Debra Mariam bearings showed deflections amounting to 18°. The rocks of the slopes of the east bank belong to the series of Plateau Basalts; their petrographic characters are quite distinct, and this is shown by examples from the Egirrbar and Arafami Hills.

The relationships of several small cones, apparently surrounded by the Bahrdar Giorgis lava, are uncertain. West of Bahrdar Giorgis is Debanji, with a crater breached

to the south-east as shown on Map III. The prevalent rock is a very spongy basaltic scoria and volcanic bombs are abundant on the slopes. Though the crater is breached there does not appear to have been any lava flow connected with this cone. Close by to the north-east is Kobiita Hill, which is formed of basalts strongly suggestive of those of the Plateau Basalts and quite distinct from the Bahrdar Giorgis lava. It may represent a former hill the base of which has been buried by the lava, but it was not possible to make a detailed examination of the neighbourhood. Kutatina Hill is the remains of a volcanic cone formed, like Debanji, of very scoriaceous rock but associated with a little, more massive material showing phenocrysts. Under the microscope it exhibits features such as porphyritic crystals of olivine and pale coloured augite that distinguish it from the Bahrdar Giorgis lava. The matrix is very fine grained. The hill is ridge-shaped, with an east-west direction, and possibly it is the remains of an older cone partly destroyed by the Bahrdar Giorgis lava, while Debanji was formed by a later eruption and pierced the lava.

Alluvium.

On the Abyssinian plateau the agents of erosion have as a rule only basalts and perhaps some trachytes to act on, and sands derived from these materials readily break down into clay, becoming practically indistinguishable from the undisturbed soils which have arisen directly by decomposition of the volcanic rock. The freedom with which the basalt decomposes not only explains the comparative paucity of sands but also of the types of alluvial topography generally associated with such deposits. It probably is not generally realized that the existence of these familiar features of the ordinary landscape depends on the nature of the original rocks and on the prevailing climate, which may or may not promote alteration of minerals. The point is borne out by observations in the neighbourhood of Delgi, where quartz sand and the usual topography associated with sand exist, including storm beaches on the lake shore.

The most important areas of alluvium occur at the mouths of streams debouching into Lake Tana and have been referred to in the general description of the topography. The covering of soil is underlain by sands and gravels, from which supplies of water can be derived by means of wells. Along parts of the margin of the Fogara plain there are storm beaches formed of basalt sand, such as the ridges observed by Mr. Buckley. Very often, however, there is no sand and the shore is a gently shelving slope of dark clay, bearing grasses and sedges.

The Blue Nile at Kutai is a torrential river with a bed of shingle in a deep valley. There are only very limited deposits of coarse shingle and gravel covered with sandy and silty soil flanking the channel.

Soils.

The soils of the Abyssinian plateau are essentially the result of the decomposition *in situ* of the volcanic rock. This has occurred under the influence of climatic conditions which have led to deep and complete decomposition of the basalt into a heavy red clay.

The alteration proceeds with a sharply defined limit between the fresh rock and the clay, and the origin of these masses of red clay is only betrayed by the occasional presence of kernels of the undecomposed rock. The red colour of the soil on the undulating parts of the plateau is a highly characteristic feature. Two samples of this type of soil collected on the plateau at Alafa have been analysed at the Wellcome Tropical Research Laboratories in Khartoum by Dr. Joseph with results as follows :—

	1	2
MECHANICAL ANALYSIS.		
Stones and gravel	0·4	0·8
Coarse sand	11·9	10·4
Fine sand	24·9	8·5
Silt	31·8	44·0
Clay	31·8	36·3
CHEMICAL ANALYSIS.		
Total salts...	0·070	0·101

Sample 1 was from the surface of the plateau about 4 miles west of Fitaurari Daboche's village. Sample 2 was from the bank of the Akli stream near the western edge of the plateau at Alafa. The basaltic soil absorbs water readily. Excavations at the Tana Mission camp at Bahrdar Giorgis proved that there was a thickness of 60 centimetres of soil resting on rotten rock. A little trench about 15 centimetres deep at the edge of a flower bed was generally filled after heavy rain, but a couple of hours later it would be empty owing to absorption, as there was no other means for the water to escape. The soil appears also to have good moisture-retaining properties but only cracks slightly as it dries in the course of the dry season, and where the high grass is eaten down it always supports a little green turf. Blanford attributed the great fertility of the Abyssinian soils to the prevalence of the trap rocks, and relates that on the sandstones and limestones of Tigre vegetation is poor, while better soil is met with on the metamorphic rocks.

The red soil is limited to the slopes and higher parts of the land and this hill ground suitable for ploughing is known as *korapta.* The hollows and swampy places are occupied by dark soils known in Shoa as *haro* and in Agaumidir as *arrâmi,* and these are subject to deep cracking in the dry season. The difference in character appears to be due to the presence of humus in the dark soil the mineral composition of which must be essentially the same as that of the red soil on the neighbouring slopes from which it has certainly been derived. This dark soil does not appear to be looked on with favour by the people, who generally avoid it when cultivating. Probably this is done for the very practical reason that the dark soil is often water-logged during the rain. Some ground selected for ploughing is thickly strewn with stones up to 30 centimetres in diameter and looks most unpromising, but this does not deter the cultivators, and the yields from such places appear to be excellent.

The dark soil seems to have been formed under marshy conditions and, in contrast to the red soil, it is very impermeable. This is borne out by the observations on the drying up of pools. Bearing in mind the higher temperature of the pools and the transpiration of the grass, the water diminished at rates quite in keeping with that established for the open lake. Blanford mentions very fertile dark soils as occurring wherever basaltic rocks prevail on the Abyssinian plateau. He compares this type with the *regur* of

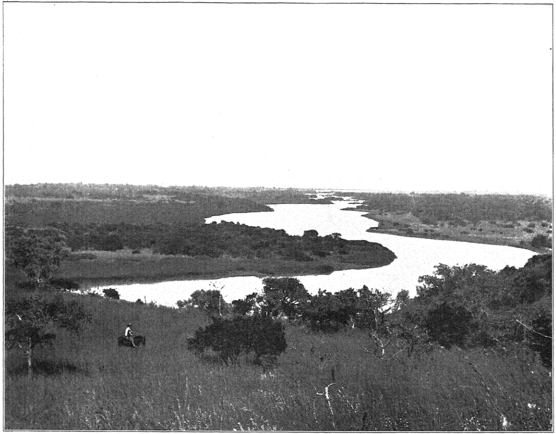
India, but such soil was not observed in the regions visited by the Tana Mission. In these, on the plateau, the dark soil of the hollows most closely approaches the *regur* type in appearance, but no attempt to cultivate it was ever observed.

Leaving the Abyssinian plateau, other types of soil similar to those of the Sudan were found along the road between Alafa and Roseires, but it seems unnecessary to enter into details of these here.

Hot Springs and Seepage from the Lake.

Before passing on to particular cases near Lake Tana, it is to be noted that hot springs are frequent in Abyssinia. The best known is certainly the Fil Waha at Addis Abbaba, where the water issues in considerable volumes at a temperature of 72° C. It is fully described in Appendix V. Nearer the lake there is a spring in the vicinity of Abolai Nigus and another at Wanzage on the Gumara river. These, especially the former, rise at considerable altitudes above the lake and it appears unlikely that their waters can be derived from the lake. Inspection of the geological section, No. 6, suggests that the basalts of the plateau rest on sandstones. If this is the case, it seems improbable that the waters of the hot springs can pass up though the sandstone, which is porous and would certainly permit the water to escape laterally before it could be driven up to the surface of the basalts above. It seems more probable that the water of the hot springs is of local meteoric origin, circulating among the basalts until it meets a source of heat associated with recent volcanic action and this, heating the water, drives it to escape at the surface. In most of the springs the water is accompanied by a good deal of gas in bubbles, perhaps nitrogen thrown out of solution by the increase in temperature, and this must produce an "air-lift" action helping to bring the water to the surface.

More interesting in connexion with the hydrology of Lake Tana are the springs which occur low down on the escarpment immediately to the west and north-west of the lake. The positions of two in the upper part of the Jira valley on the road from Delgi to Gallabat are shown on Map II. Mr. Barron recorded two hot springs at the lower levels and a warm saline spring higher up the valley, and stated that people reported the existence of two other springs in the Jira valley and another in the Atbara valley not far to the north-east. The water of the hotter of the springs seen by Mr. Barron was far too hot for the hand to bear. These springs are in much the same position relatively to the escarpment and the lake as the hot spring indicated on Section 6 at the foot of the escarpment below Alafa, and it seems quite possible that they are all fed by seepage from the lake. There may be others along the foot of the escarpment, but unless they occur in fairly accessible places near routes, it is very improbable that they can be generally known. The water passing down through the depth of basalts below Lake Tana to the level of the springs would certainly attain a considerable temperature. However, the total discharge represented by fifty such springs as those just mentioned would hardly exceed two or three cubic metres a second. Even if this amount is doubled or trebled to allow for water that may escape from the bed of the lake in other directions, some may pass into the porous sandstone below the basalts, the total loss by seepage is practically negligible as the evaporation experiments have shown.



No. 14.—The Blue Nile Channel leading from the Outlets of Lake Tana.

Description of the Outlet.

General Aspects.

The general relationships of the rocks at the outlet has already been described and it was seen that the lake has been formed as a result of a lava flow which came from the west and choked the Blue Nile valley at Bahrdar Giorgis. The water subsequently overflowed, finding its way along the lowest line situated where the lava flow meets the eastern slopes of the valley. The consequence is that the rock of the slopes on the left bank belongs to the series of Plateau Basalts, while the plain on the right is formed by the uneven surface of the lava. This is generally true, but there is often a narrow belt of the lava at the foot of the slopes of the left bank. Another feature is that, where there are spurs on the east slopes as at Bezeit Allen, Egirrbar and Arafami, the river channel is narrow, as if the lava had pressed against the projections. On the other hand, in the bays between the spurs the river occupies a wide channel, usually with many islands. Another general feature is the absence of any signs of erosion along the river near the outlet and the water can be regarded as passing along the channel almost as it existed just after the eruption. The only modifications are due to silt brought down by the Chimbil stream, and this has resulted in the formation of little alluvial banks on the east side at Kamforo, and it has no doubt helped to produce soil to fix the papyrus in bays flanking the channel. The extreme slowness of any erosion was shown by comparing conditions at Chara Chara in 1921 with those photographed by Mr. Dupuis 18 years before. The number of loose boulders might suggest the possiblity of change, but on comparison it was found that the scene could be identified boulder by boulder and not one of them has been recognized as having changed its position.

The Shores of the Lake.

The character of the surface of the lava has been referred to. The hummocky surface typical of recent lavas in Abyssinia tends to become obliterated as the rock weathers and the hollows are filled with soil. At Bahrdar Giorgis the process has already proceeded some length, and to the south of the village is a plain nearly a square kilometre in extent, where irregularities of the surface are hardly discernible, but their presence is still indicated by stony patches. In other places the rock was found below about 60 centimetres of typical red basaltic soil. There is nothing to distinguish the soil on the lava from that of the slopes of the east bank, which is certainly formed from much older rocks. These, however, show deep decomposition, as for instance at Tayima and Burifasas.

The shore of the lake near Bahrdar Giorgis is rocky and rises steeply from the water to a height of nearly six metres above water lèvel. This rocky shore is interrupted at intervals by deep bays filled with papyrus swamps as shown on Map III. The rocky slopes of the shores continue for a few metres below water level, and the floor of the lake near the outlet, with the exception of a few outcrops of rock, is formed of a fairly compact clay or mud. The depth of this clay is not known, but, so far as it extends, it may be easily dealt with in forming the approach from the open lake to the regulator when water levels have to be controlled below certain limits. The highest part of the land near Bahrdar Giorgis is fairly close to the shore and from the village it slopes distinctly in a south-easterly direction, so that, at a distance of only two kilometres south-east, the surface is below the level of the lake.

The Outlets.

The northern limit of the lava on the shore of the lake is probably not far north of the outlet at the north end of Debra Mariam Island. The swampy shore of the mainland, with its belt of papyrus marsh, as well as that of Debra Mariam Island, however, is underlain by the lava, which is only covered by a thin bed of soil. The bare rock forms all the islands as well as many shoals just below water level both in the entrance channel of Abbai Ras and to the west of it, as shown by the hatching on Map IV. As regards the location for an earth bank to close the outlet, this will almost certainly be chosen to take advantage of the line of islands, Photograph 24, across which the line of Section 1 is drawn, and on the north it will tie on to ground underlain by rock at a shallow depth. The level of the surface is low and the end of the *sadd* will have to be extended eastwards to meet higher ground. There is plenty of rock showing at high stage level on the point of Debra Mariam Island to form the abutment for the southern end of the *sadd*. The rock rises to about R.L. 82 on this end of the island, but it is almost separated from the main portion to the south by a narrow neck about 300 metres from the point. The neck is also formed of rock and there is a flow of water across it at the higher stages of the flood. This may be readily closed by a small earth bank, provided the water is not to be held up above R.L. 81. Between the neck and the open lake there is a large island formed of rock rising little above high flood level, with a good deal of swamp along the lower parts of the shore. The mainland east and south-east of Abbai Ras has a good deal of papyrus swamp which all seems to be underlain by rock at shallow depths. It is exposed at the landing place, where the hatching appears on the map, and proves to be the massive variety of lava which forms the lower slopes up to 4 or 5 metres above the lake. At the back of the swamps, which flank nearly the whole of the mainland shore of the Debra Mariam Lagoon, the ground rises and the slopes continue steadily upwards until they culminate in hills hundreds of metres above the level of the lake. The western shore of the lagoon is formed by the main portion of Debra Mariam Island consisting of the lava capped with soil rising to about two or three metres above the flood level of the lake.

The outlet, Frontispiece II, at the south end of Debra Mariam Island is flanked on the south side by Shimabbo Island, where the surface of the land rises to about 2 metres above flood level. Similar levels are attained by the ground on the Debra Mariam side and in both cases the surface is immediately underlain by the rock of the lava, which is exposed along the greater part of the shore of the channel. The surface of the lava is covered with loose blocks of the original crust of the flow, and for the purpose of a foundation surface for masonry these must be removed and an allowance of about 2 to 3 metres should be made below the existing surface. As far as present evidence goes, it can be stated that with this allowance of 3 metres there is every reason to expect a thoroughly good surface on which to base foundations. The rock is likely to be traversed by close joints, and though there may be a little seepage there is no soft material to wash out and endanger the stability of foundations. Any works constructed on this channel must deal everywhere with the lava for foundations and abutments. The north bank of the channel rises continuously to levels well above the flood level, but on the Shimabbo Island side there is a gap, with a sill about 50 centimetres below flood level, and water flows across it at the higher levels of the lake. This gap is situated nearly opposite the southernmost point of Debra Mariam Island and could very easily be closed by an earth bank, but the regulator may be designed to abut to the west of it and then the gap would be of no consequence.

When Mr. Herbert arrived to carry on the work of the Tana Mission, a good deal of surveying was still required in the outlet channels, but levels on Shimabbo Island were complete enough, Map IV and Section 1, to show that, along the western side of the island, there is a continuous strip of land extending from the side of the gap just referred to, to the shores of the Ifwadda Lagoon. This lagoon forms a third outlet and must therefore also be closed by any system of works designed to control the waters of the lake. The whole island is underlain by the lava, which is exposed along the shores except where these are marshy, and, even in such places, the rock exists at quite small depths below the surface of the soil. Photograph 25, taken from the top of a tree south of Ifwadda Lagoon looking north-west, shows this outlet, which may be completely closed by a *sadd* crossing it on the line of Section 1, shown on Map IV. This would abut against the end of a ridge extending westwards and joining high ground, which is continuous west of Mariam Sar depression to the higher part of the lava near Bahrdar Giorgis village. The section line shown on Map IV does not follow the ridge but extends southwards, crossing the Mariam Sar depression, which is noted for the thatching grass it produces. The mainland side of Ifwadda Lagoon is broken by some extensive papyrus swamps and these would be completely cut off from the lake if the other outlets are closed and the Ifwadda *sadd* is placed in the position shown on Frontispiece I. South of the path and separated from the lagoon by a ridge of high ground is an extensive papyrus marsh the limits of which are marked on Map III. The northern edge of the marsh is bounded by fairly steep slopes of lava blocks and appearances are strongly suggestive that the water supplying the marsh is seepage from the Ifwadda Lagoon or from swamps on its shores. If this is the case, this swamp too would dry when the lagoon is dried. Under existing conditions a part of the marsh continues waterlogged almost throughout the dry season. The water from Ifwadda now reaches the cataracts at the head of the river by means of channels around Ifwadda and Grastaal Islands. These are rather low-lying and support a good deal of payprus marsh, but both the islands and the channels are underlain by the lava. The floors of the channels on either side of the south end of Grastaal Island are dry when the lake falls a little below R.L. 80·00. The flow from Ifwadda Lagoon might be cut off by a smaller bank crossing these channels from a little north of the "tree on wall," shown on the Upper Reef, to Shimabbo Island. The cube of material required to make a bank here would be smaller, but the swamps around Ifwadda would remain. The country at the end of the lagoon and towards Kamforo is shown in Photograph 11.

The Cataracts.

The most remarkable feature of the outlet now falls to be described. This is the Upper Reef as it has been called by the Tana Mission. It consists of a well defined reef generally less than 50 metres wide and rising 5 or 6 metres above the level of the surrounding country. It is shown on Map IV and its profile is given in Section 2. It is highest at its southern end, where it abuts against high ground south-west of Kamforo ferry. From this point it runs northwards, flanked on both sides by low ground, which is swampy during the high stage of the lake and the rains. In this part there is a low place where the level falls to 81·84 and another where it falls to 82·53, but there is no sign at either of these of water having escaped. It could only reach the level of the lower gap in a year of very exceptional flood. The height of the reef decreases as it is followed northwards, and water from the lake passes over low places in it, forming six distinct cataracts. Mushasha, the most southern of these, is flanked by fairly high ground and

carries some water throughout the year. North of it there are two small cataracts which only carry water during the highest stages of the flood. Proceeding northwards, this part of the reef only rises about 50 centimetres above the level of the flood of 1920 and during the highest stages the water passed through crevices among the blocks forming the surface of the reef. Abbat Izani, met with next, is the most powerful cataract at all seasons and in 1921 the water never fell so low as to permit it to be forded. Gilgil Izani is a long cataract immediately north of Abbat Izani and though it must carry a considerable volume of water during flood it becomes fordable fairly early in the season. The sill is nearly 50 metres long and water passes among the loose blocks throughout the dry season. To the west of this part of the reef there are a number of islands and shoals occupying the space that extends to Shimabbo Island. The levels of the rock in these shoals is high and would make it very costly to open a passage connecting the southern Debra Mariam outlet with the river below Abbat Izani. North of Gilgil Izani the Upper Reef pursues its direction, forming an island beyond which it may be regarded as bending round to meet another ridge forming the east bank at Chara Chara and making the sills and rocks around this cataract. This is the most important cataract from the point of view of works intended to control the level of the lake without raising the water levels above those of the ordinary natural flood level. It affords the easiest line for a channel to connect the southern Debra Mariam outlet with the river below the reef. The section along the sill is shown as a dotted line in Section 2. The full line refers to the line shown across the middle part of the cataract in Map IV and longitudinal details are included in Section 3. Chara Chara Cataract is shown in several of the photographs. Nos. 22 and 23, taken from the east bank, show the cataract under flood and low stage conditions. The floor of the cataract, on which rest the boulders seen in the picture, is massive jointed rock, and provided the loose and open jointed material is removed, it would make a thoroughly sound base for foundations, should it be desired to build a work in this vicinity. The joints may permit a little seepage, but, as already noted in describing the southern Debra Mariam outlet, this will not in any way endanger the stability of foundations. Photograph 27 is from the west bank and shows the rocky islands at the head of the cataract. These consist of spongy looking vesicular lava with wide joints at the surface, but are certainly underlain by closely jointed compact rock. The eastern shore of Chara Chara, being the mainland, is easy of access at all seasons and consequently is the view of the outlet most generally obtained by travellers. In order to reach the other cataracts during the flood season, strong currents among rocks must be negotiated, sometimes with the knowledge that return is impossible and a way out must be found in another direction.

There is no point of vantage from which a comprehensive view of the reef, the cataracts and their approaches can be obtained, but Photograph 26, from the top of a tree just south of Abbat Izani, shows this cataract in the foreground on October 23, 1920, and in the distance on the right is Chara Chara. No. 28, from the Lower Reef downstream of the cataracts, shows Chara Chara on the right with Gilgil Izani and Abbat Izani towards the left, as they appeared on February 28, 1921. The drop in levels across the Upper Reef during flood is rather more than 1·5 metres and each of the cataracts have approximately this fall. The Upper Reef is to be regarded as a natural dam which holds up the waters of the lake, in fact it might be said to have been designed by Providence to facilitate the utilization of the water of the lake for the benefit of cultivators in the Sudan and Egypt without need to interfere with the amenities of people living around the lake. It is obvious that, with a nearly horizontal sill such as the Upper Reef provides, a small increase in the levels

upstream of it above certain limits may involve a much increased discharge. The water of the lake has however to pass through the various outlets before reaching the Upper Reef and these do not offer much increased widths as water levels rise. At high levels, therefore, they become the controlling factors in the discharge of the lake, while at low stage the levels are maintained by the Upper Reef. During the highest stages of the 1920 flood, the current through the southern Debra Mariam mouth could just be negotiated with a *tankwa*. The current through the northern outlet was too rapid for such a craft, and here, on account of its width, any rise in levels must involve a considerable increase in the discharge. The low gap a little way south of the northern outlet is fringed with sedges and does not suggest that any rush, such as would be associated with a lake level of 81·30 metres, is frequent, as the plants would certainly be torn out. Besides these, there is the outlet through the Ifwadda Lagoon, but the Channels are devious and fringed with papyrus and other sedges, so that they do not appear ever to be subject to fast currents. At low stage the current through the Debra Mariam outlets is hardly appreciable.

Just east of the Upper Reef is the Lower Reef, and though this is less clearly defined, it can be followed northwards from near Kamforo ferry in a series of discontinuous mounds and ridges parallel to the Upper Reef. The southern part can be regarded as forming the west bank of the Blue Nile, but there are pools and swamps between it and the higher ridge to the west, and there is a flow through some of these during the higher levels of the flood. Towards the north, the Lower Reef diverges from the Upper Reef, forming three islands during flood which become continuous when water levels fall. The greater part of the river passes over a small cataract at the southern end of these islands and there is always some flow around the northern end, just below Chara Chara. The fall in these cataracts during flood amounts to about 30 centimetres. On the east sides of the two northern islands there are extensive swamps which would doubtless coalesce, were it not for the stream that passes between and separates the northern island during flood. The northern end of the Lower Reef can be regarded as extending northwards and forming the eastern side of Chara Chara cataract, which passes where the two reefs meet. The parallelism of these reefs is too remarkable to be fortuitous, though nothing at all similar has been observed elsewhere in the first reaches of the Blue Nile. It seems that they must be connected with the manner in which the lava impinged against the eastern slopes of the valley. The flow came from the west, and at this point it must have abutted directly against the slopes, while both upstream and downstream the lava must have tended to flow parallel to the valley sides. The reefs seem to have been the result of a hard crust being driven forward by the still plastic lava underneath.

Chimbil to Kamforo.

The River Chimbil enters on the east bank with a well defined mouth containing a backwater at all seasons opposite the island formed by the northern end of the Lower Reef. It is the first tributary of the Blue Nile below Lake Tana and is torrential in character. Where the path crosses the stream about 500 metres from the outlet the bed is about 10 metres wide and there are indications such as debris on branches, showing that the water may rise to a height of 3 metres. It seems likely that a discharge of 10 cubic metres a second is frequently attained during the rains and this may be considerably exceeded for short periods under exceptional circumstances. On October 12, 1920, at a point a little way below the path, it was found to have a sectional area of about 10 square

metres and a maximum surface velocity of 0·24 metres a second, indicating a flow of about 1·5 cubic metres a second. The influence of this stream was seen on occasions, especially during the early stages of the flood, when its discharge was enough to make the whole river turbid. The silt supplied by the Chimbil has helped to modify the river channels by filling hollows and building banks. The land on the left bank generally slopes right down to the river, but this is interrupted for a short distance south of the mouth of the Chimbil where there is low lying ground, marshy at all seasons, flanking the high berms of this torrential stream. The swamps against the eastern sides of the Lower Reef islands opposite the mouth of the Chimbil seem to be due to the silt it has supplied. Before the advent of the lava, the Chimbil must have continued down the slopes to meet the main river at the bottom of the valley. The lava has filled up all this and consequently must be relatively deep opposite the mouth of the Chimbil.

In spite of the silt from the Chimbil, the river flows in a very uneven channel, as shown in Map IV and Section 3. There is a deep hollow with a floor below R.L. 74 metres between the Upper and Lower Reefs in front of Gilgil Izani, another long hollow at one point reaching a level of R.L. 67 metres just downstream of the Lower Reef, and at Kamforo ferry there are depths to levels below R.L. 70 metres: besides these there are several smaller ones, the positions of which are shown by the contours on Map IV. The soundings showed that, while a considerable part of the river bed is in rock, there are large areas of sand and mud. The rock channel is therefore likely to be even more irregular than appears. These deeps in the channel are extensive enough to make a material reduction in the quantity of excavation required to form an even channel along the bed of the river. The bed is flanked on both banks by lava, and between the deeps in the bed, are rough rocky ridges over which the river flows in rapids among islands during the lower stages of the lake. It does not appear that there can be any hope of finding silt blocked channels around these ridges and there is little doubt that hard rock must be excavated to form channels through them. The position of the ferry is shown on Maps III and IV and it plies from a rocky shore on the west, Photograph 7*a*, to a low alluvial bank on the east. About 200 metres upstream of the ferry is a rocky reef where the river can be forded between January and July in normal years. The alluvium, doutbless arising from the Chimbil silt, forms a berm on the east side of the river with a hollow just behind. Beyond this, there are outcrops of lava just at the foot of the slopes rising up to Tayima Hill, which is the nearest point to the outlet that offers a comprehensive view of the river. It is formed of basalt with conspicuous porphyritic felspars as much as 1 centimetre in length in a fine grained ground mass, quite distinct in character from the lava. The exposures are not enough to allow the relations to be observed, but there are traces of vertical jointing suggesting that the rock forms part of a horizontal sheet. From the summit of the hill the lake is seen in the distance stretching southwards to Bahrdar Giorgis village; Ifwadda Lagoon appears nearer among the vegetation and the river passes just below the hill. The system of outlets and cataracts by which the river escapes from the lake is too complex and distant to be discerned, but the river can be followed downstream to where it impinges on the slopes of the Burifasas Hills below Bezeit Allen.

Kamforo to Burifasas.

The detailed surveys ceased in 1921 a few hundred yards below the ferry, consequently the reaches beyond can only be described in more general terms. Such information as we obtained is presented in Section 4, in which the flood level and the profile of the river



No. 15.—Faras Egr Falls from Egirrbar Hills.

bed is tentatively connected with the surveyed points at Burifasas and Egirrbar discharge sites and thence to Jirmidi, where the flood level was also known. The channel continues to be flanked on both banks by the lava as far as the Burifasas Hills, where the rock of the Plateau Basalts comes right down to the water. A comprehensive view of this reach is obtained from near Bezeit Allen, Photograph 14, and the irregularity of the channel may be seen. This is displayed on Map III, which shows that the channel alternately widens and contracts and that some fairly extensive bays on the west are filled with papyrus swamps. At the contractions there are rapids among rocks and perhaps, in the wider parts, there may be hollows of considerable depth filled with silt. In calculating the cost of excavating a channel, however, solid rock must be assumed along the whole of this channel unless evidence is obtained by borings. This reach can be regarded as ending in a narrow channel with nearly parallel rocky banks at Burifasas. This afforded the nearest practicable discharge site to the lake during flood. The water is held up by the sill of a cataract immediately downstream and at low stage the velocities at the discharge site are too small to yield satisfactory results, while at high stage there is a relatively small range of levels owing to the great width of the cataract. The locality is shown in Photographs 19 and 20. The former, taken in a south-west direction from the upper part of the slope on the east bank, displays the discharge *tankwa* in mid-stream, a small channel branching towards the west and the cataract downstream. The latter, taken from the west bank, shows the discharge arrangements and the steepness of the opposite slopes.

Burifasas to Egirrbar.

Immediately south of the discharge site, the river channel expands and a narrow channel divides to the west. In the main branch of the river there are rapids about 300 metres wide during the flood and at low stage the stream is contracted, shallow, and offers the easiest ford for pack animals near the outlet. Below the rapids the river flows in a wide, marsh-flanked channel, turning westwards at the base of the Egirrbar Hills. The little western channel from Burifasas carries a considerable discharge during the flood and contains rocky falls corresponding to the rapids in the main stream. The west flowing reach where the western channel rejoins the main stream is wide, contains a large number of rocky islands and is flanked by an extensive marsh on the north-west. Photograph 29 shows the view over this on April 12 from the north-west spur of the Egirrbar Hills, which rise on the east bank opposite Egirrbar. The surface exposures are enough to show that any excavations following the shorter course along the western channel from Burifasas must deal with solid rock throughout the whole distance. On the bend of the main channel just below Burifasas it is possible there may be hollows partly or entirely filled with silt, and if these exist, excavation would be much facilitated on a line through them.

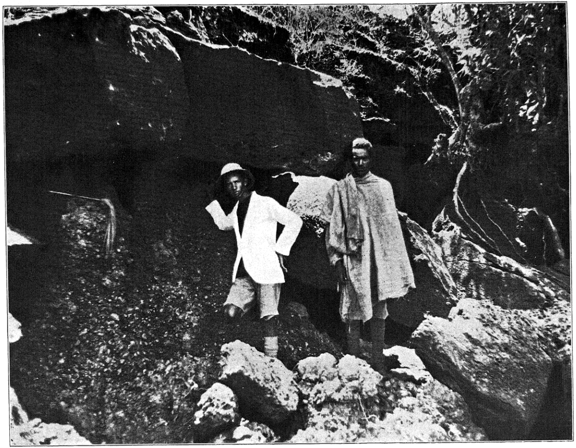
At Egirrbar the channel narrows, and with the small slopes in the upper part of the reach, conditions during low stage were convenient for measuring the discharge of the river. This appears in Photograph 5, which also shows the character of the lava country west of the river with groups of trees marking the positions of hummocks and the grassy hollows between. The hills on the east bank are formed of horizontally bedded basalts, and their structure is well displayed on the south-east face of the spur. The rock on the summit is a dark, compact, fine-grained basalt without conspicuous crystals. The microscope shows little porphyritic crystals of basic plagioclase felspar in a fine grained microlitic ground-mass without conspicuous olivine. If a tunnel is made on the line through these

hills shown on Map III, the excavations will have to deal with bedded basalts. If the line happens to pass at the junction of two beds, the work may be facilitated by the presence of a good deal of scoria and ash. The centres of the flows will prove to be hard and probably roughly jointed into irregular vertical columns.

Egirrbar to Arafami.

Below the discharge site the gradient of the river becomes steeper, so that the stream forms rapids among rocks until it bends around the spur of the hills and flows north-east down the Faras Egr falls shown, on April 12, in Photograph 15. The bed of the river here is formed of a rhyolitic breccia. The matrix is rather decomposed, but it is essentially rhyolitic, while it contains fragments ranging from a stony, banded rhyolite to a glassy obsidian. The rhyolite is pink to brown with hardly any felspar phenocrysts ; the obsidian is black, generally traversed by perlitic cracks and contains drawn-out vesicles which appear as points on fractures in one direction and as lines in other faces. The right bank is formed of low cliffs, with good sections where the Bahrdar Giorgis lava is seen resting on the surface of the rhyolitic rock as shown in Photograph 16. The base of the lava is very well defined and there is no scoria associated with it. The lowest part of the lava is vesicular, but within a metre it passes into a massive rock, showing crystals of felspar and olivine. The base of the lava bears impressions of irregularities in the original surface of the rhyolitic rock which must have been fairly even when the lava flowed over it. The underlying rock has since suffered erosion, partly by the stream but also as a result of waters which have penetrated along joints in the lava and flowed on its surface. In this way the marginal parts of the lava have been left unsupported and many blocks have fallen over. The relations of the rhyolite to the bedded basalts of the hills on the left bank have not been made out. It may represent a vent but judging from its extent, it is more probably a bed.

The reach of rapids and falls at Egirrbar and Faras Egr, just over 9 kilometres from the lake, has a fall of about 8 metres during flood. The falls debouch into a deep pool and the stream then flows through a narrow and very deep channel, where the Jirmidi ferry plies. The depth of the channel is shown by the sluggishness of the current even during the flood. Downstream of Jirmidi, the river turns to the south-east, the bed widens and the water flows in a number of channels among a maze of islands for a distance of nearly two kilometres until the bed contracts at the Arafami falls, shown in Photograph 6. This view was taken from a commanding little hill immediately north-east of the falls and generally refered to as Arafami Hill. The outlines of this region on Map III show that the river curves around a bay flanked by the Egirrbar and Arafami Hills. It has already been remarked that the former are composed of bedded basalts and these extend to Arafami Hill, which is composed of an almost flinty basalt finer grained than that of Egirrbar Hills. The exposures are too poor to allow the relations of the rock to be observed, but it is jointed into vertical columns, suggesting a horizontal sheet. At the base of Arafami Hill are outcrops of the lava, which here, as we have seen elsewhere, has abutted against and adhered to the lower part of the slopes. Upstream of Arafami the river is flanked on the east by a stretch of low ground in the bay among the hills and this was found to be underlain by the lava, which doubtless spreads over a considerable area of the low ground and abuts against the slopes. The sill of the Arafami falls is formed of the jointed and broken lava



No. 16.—The Base of the Lava Flow.

and there is a fall of nearly 7 metres at low stage. Their position is on either side of a small island immediately south-west of the hill and just where the red line ends on Map III. It is about 250 metres upstream of where the name is placed.

This description has been limited to the immediate vicinity of the river, but looking across to the south, the surface of the lava can be seen forming the floor of a wide valley bounded by steep slopes of bedded basalts which are the upper parts of the original valley slopes. The river lies on the north-east side and streams such as the Andassam, draining from the hills to the south, flow eastwards down the slope of the lava floor until they join the Blue Nile.

Depth of the Lake.

No direct evidence as to what depths are attained by the lake was obtained by the Tana Mission. Statements occur (1) that depths in the southern part of the lake range between 30 and 70 metres and this agrees with a depth of 40 fathoms given in another general work,(2) while the Italian map notes that the greatest depth is about 100 metres, doubtless based on Stecker's work. The other figures may be the results of soundings, but it has not been possible to trace their origin.

The lake being formed as the result of a lava dam across the Blue Nile valley, the deepest part of it must be at the northern edge of the lava at Bahrdar Giorgis. The lava extends down the valley to beyond the Alata or Agam Bridge, but there the river is still at the side of the valley, and though it flows on rocks older than the lava, the deepest part of the original valley, is almost certainly still covered by the flow. The level of the bed at the bridge is 1,680 metres and the former bed in this part of the valley may have been at about 1,640 metres. On such assumptions and allowing for the slope of the valley, the lava at Bahrdar Giorgis may be rather over 100 metres thick and the greatest depth of the lake rather less, or about 80 or 90 metres. This must have been reduced by the accumulation of silt and therefore agrees well with the reported depths mentioned above.

A depth of 70 metres and a width of about 70 kilometres suggests slopes of about 1 in 500 and this would represent a reduction in area of rather less than 4 per cent if the level of the lake was lowered a metre below its normal level. This figure seems preferable to that adopted for calculating the capacities of the reservoir (*see* Chap. VII, p. 83), which depends on the assumption that estimates of the shore slopes would hold good through a depth of four or five metres below 81·00.

Age of the Lake.

The general condition of preservation of the crust of the Bahrdar Giorgis lava and the limited amounts of soil both point to its having been erupted at a relatively recent date. There is, however, no criterion available enabling us to say how fast the rock decomposed into soil and what lapse of time the present conditions represent. Alluvial deposits are associated with the outlets of all the more important rivers that discharge into the lake. If the discharge of one of these rivers and the amount of silt carried in suspension were acccurately known, as well as the area and thickness of the alluvial deposits, it would be possible to estimate the age of the lake on the assumption that similar climatic conditions

(1) H. G. Lyons, "Physiography of the Nile and its Basin," p. 216.
(2) A. H. Keane, "Africa," London, 1895, Vol. I, p. 462

had prevailed all the time. The Fogara plains, due to the Reb and Gumara rivers, have an area of about 300 square kilometres. If the alluvial deposit is on an average 10 metres thick and there is an area of detrital deposits of about half the size below the surface of the lake, these assumptions lead us to suppose that 4,500 millions of cubic metres of silt must have been supplied. This, at the rate of 1·8 metric tons to the cubic metre, represents just over 8 thousand millions of tons of silt. Now, if the Gumara, Reb and other streams contributing to the formation of the Fogara plains discharge silty water at the rate of 100 cubic metres a second for 100 days each year, and this carries 1 part in 500 in suspension, it amounts to 1·7 million tons of silt a year and about five thousand years would be required to build these plains. The volume of silt represented by the plains may have been under-estimated, but this is compensated for by extra detritus due to the bottom load of the streams, since our estimate was based only on the material carried in suspension. While attaching very little importance to the figures, they are of interest as supporting the view that the lake is of recent origin. The age may just as well be 10,000 years as 5,000, but whatever it is, it conforms to the youthful appearance of the many volcanic cones on the southern shore of the lake. The formation of Lake Tana can have had no effect on the regimen of the Nile that would have been noticed by people in Egypt. The river previous to the formation of the lake would have been slightly larger during flood and rather less during the falling stage immediately afterwards. At low stage there could have been practically no difference, as the tributaries must have discharged as much as the lake now contributes.

It is quite obvious from the figures given that the rate of silting in the lake is so small as to have no influence on its value for use as a reservoir.

Character of the Lake Water.

This does not change appreciably from season to season. The water is dull green in colour and always has a distinct greenish brown turbidity, apparently due to clay associated with microscopic swimming plants, such as diatoms, and even white objects cannot be seen at depths greater than about 50 centimetres. Plants and rocks under the water, especially in the Ifwadda Lagoon, are often coated with a thin layer of mud, and since, except for a little rain water running in from the shores, there are no tributaries, it seems likely that this must have been raised by swimming plants. The turbidity is hardly noticeable in small quantities of water such as in tumblers or washing basins. The water itself then seems very pure, has no taste or smell and is evidently very soft, making no appreciable curd with soap. Possibly it may be very slightly alkaline and this would be in keeping with its softness and the turbidity.

Samples of the water were collected and brought to the Government Analytical Laboratory, Cairo, where the following results were obtained :—

	Sample I	Sample II
Date of collection	February 25, 1921	May 20, 1921
	Parts per million.	Parts per million.
Total solids	162·0	174·0
Chlorine as Cl	8·0	5·5
Equivalent of Cl as NaCl	13·2	9·1
Sulphuric Anhydride, SO_3	Trace	Trace
Lime, CaO	38·0	32·0
Magnesia, MgO	16·6	8·5



No. 17.—Lichen Line and White Belt.

It was remarked that Sample I smelt strongly of sulphuretted hydrogen and II contained diatomaceous matter in suspension. The late Mr. F. Hughes expressed his opinion that the waters were quite suitable for purposes of irrigation and remarked that the absence of sulphates was accounted for by the samples having been kept long in tightly-corked bottles. Both the samples were taken in the dry season and the quantity of solids in solution is distinctly greater in the later one. The presumption is that the amount of solids in solution is least at the end of the rainy season and gradually increases as the dry season wears on, but samples should be taken at regular intervals and analysed, to obtain accurate data on this point and also to study variations from year to year. It is of interest to note that the composition of the lake water in May is rather similar to that of the Blue Nile in its lower reaches at the same season. Earlier in the year, the lower Blue Nile seems to have decidedly less in solution than the lake.

Flood Marks.

The shores of Lake Tana exhibit two natural markings related to flood levels and on the cataracts grows a weed which, though not related to definite levels, has some importance in regard to the hydrology.

The White Belt.

This had been observed by Mr. Buckley, who found it most reliable as a reference datum at various points around the lake. It appears in some of Mr. Dupuis' photographs and though not referred to specifically, he doubtless considered it in making his estimates of flood levels. On arrival of the Tana Mission at the lake at the end of July 1920, no trace of any white belt could be seen, and so complete was its absence that it seemed as if perhaps the 1915 flood had been exceptional and the white belt was not formed each year. After the flood the first trace of the belt was noticed on October 8, as a gelatinous coating to the rocks with a slimy feel. A fortnight later the lake had fallen enough to allow the upper margin of the belt to dry and it appeared as a conspicuous white line just above the level of the water. As the lake fell, the width of the belt increased and its appearance on March 10, 1921, is shown in Photograph 17. The sharply defined character of the top of the belt is clear from the picture and even little knobs of rock a few centimetres across, happening to project above the limit, are left free of the white deposit. Mr. Black and Yanni Eff. were able to refer the level to bench-marks, obtaining a mean value of 80·92. The constancy of its level is shown by figures obtained at Delgi, given in Chapter II, and this is attained in spite of considerable instability of the lake surface owing to waves and seiches. It might be thought that such a well defined belt must indicate the maintenance of a steady level for a considerable time, but this is not the case. The seiches cause variations amounting to over 10 centimetres on either side of the mean, and the lake is often stormy with waves of considerable size. The highest water level observed was 81·05, while the highest mean in the five-day periods of Table V is 80·95 or 3 centimetres above the top of the white belt. The mean lake level was above 80·92 for almost exactly three weeks and Mr. Black suggests that the organism requires that period to develop, so that it does not appear on surfaces that are below the mean level for less than that time. Though

the top of the belt does not quite represent the highest mean level during the flood, it can probably be relied on to indicate a level only two or three centimetres below and is therefore a datum of very great value. A piece of stone bearing some of the white deposit that forms the mark was taken by Mr. Buckley to the Government Laboratory in Cairo where Mr. Lucas identified the main constituent as diatoms belonging to the genus *Surirella* associated with traces of dried and partly bleached filamentous algæ. The microscope shows the principal diatom as flask shaped, with a tendency to split longitudinally into three segments. The growth seems to thrive best at the time of the flood. The deposit is whitest at that level and hollows in the rock were found partly filled with cakes of the diatomaceous material. At lower levels it seems to become less pure and is not so white. Mr. Buckley found that the dry deposit was easily removed by washing it lightly with water and concluded that the mark seen in the spring of 1916 was due to the flood of 1915, the trace of former marks having been obliterated by rains. This deduction was borne out by the absence of any trace of the mark in August 1920 after a considerable quantity of rain had fallen. The only mark that might then have been attributed to flood levels was a distinctly darker zone and subsequently this was found to characterize the rock just above the white belt. Possibly the action of the waves frees that part of the rock from dust and dirt that adhere elsewhere. The value of the white belt as a datum largely depends on its being washed away by the early rains, a "clean slate," so to speak, being prepared to receive the record of the coming flood. Our observations, however, did not extend into the early rains of 1921, consequently we were unable to watch the obliteration of the old flood mark, but all the indications suggest strongly that the white belt is obliterated each year and clean rocks subsequently receive the mark of the new flood. The flood attains its highest levels at about the beginning of October and the organic deposit does not dry to form the top of the white belt until about two weeks later, when almost all the heavy rains are over.

As a consequence of the existence of this white belt, the height of the flood may be ascertained, within a small margin of error, at any time during the following dry season. The datum can be referred to at any rocky point around the shores, and, if continuous observations cannot be maintained near the outlet, the white belt would permit the level of the flood and perhaps even the approximate date of the highest readings to be estimated as the result of a single visit during the autumn. The white belt seems likely to be quite important when the upper limits of reservoir regulation have to be discussed with the Abyssinian authorities. It forms a datum outside the possibility of any human interference or errors.

The Lichen Line and Maximum Levels of the Lake.

This lichen line appears clearly on Photograph 17 and is separated by a belt of clean, dark rocks from the top of the white belt described in the last section. It is due to a growth of lichens on the rocks and its lower limit is well enough defined to show that it is of some significance in regard to lake levels. The lichens grow on rocky shores of the open lake as well as on the more exposed parts of the islands at the mouth of the Ifwadda Lagoon. In sheltered places, other vegetation comes to the water's edge and the lichen belt is not well defined. Levels were taken and the value 81·76 was obtained as a result of a number of settings of the levelling staff in different places. This is almost exactly 80 centimetres above the highest mean level of the lake and between 30 and 40 centimetres above the wash of the waves at the highest levels. Lichens appear to be plants of very



No. 18.—Cataract Weed at Chara Chara.

slow growth and it seems that the lower limit on these rocks represents the highest limit of wave action in years of very high flood. They would be soon destroyed if they were within reach of the waves and this would account for the consistently defined lower limit to their growth. For this reason it has been assumed that such floods rise between 30 and 40 centimetres above levels attained in 1920 and 81·30 has been adopted as representing the mean maximum in those years. It was noticed that at the highest levels of the flood in 1920 there was a good deal of floating vegetable debris on the river. It is conceivable that when exceptionally high levels are attained by the lake, masses of papyrus, etc., may be loosened and floated off, and these, if sufficiently large, might choke some of the cataracts. If this occurred it would certainly cause the lake to attain very high levels. There is, however, no evidence of such blockage ever having occurred and it seems that 81·30 metres is a perfectly safe figure to accept as representing the level of a very high flood.

THE CATARACT WEED.

In August 1920, before the flood arose, the cataracts were visited and the rocks over which the water was rising were clean. As the level of the water dropped after the flood, a marked growth of weed was exposed on the cataract and this is shown on rocks at Chara Chara on January 20, 1921, in Photograph 18. The natural history of the plant, *Rotala repens*, is fully dealt with in Appendix II and it suffices here to consider its influence on the river. It is obvious that the growth of such quantities of weed on the cataracts must have the effect of raising the effective sill, consequently the discharge corresponding to similar levels must be greater when the lake is rising than, when it is falling. This has been investigated by Mr. Black, who concludes that the influence of the weed is appreciable when the level of the lake falls to 80·50. It causes a reduction of 6 per cent in the discharge at this level, increasing to 16 per cent at 80·10. At levels below this, the influence of the weed decreases until the low stage level of the previous season is reached, below which the rocks are clean and normal conditions are maintained throughout the year. If the lower limit of the growth of this weed were better defined, it might be adopted in the absence of other data as approximately representing the low stage level of the river in the cataracts during the previous year. If the discharge corresponding to this level were also known, the level of the lake during the lowest stage in the previous year might be inferred from the discharge curve.

Origin of the Red Water of the Nile.

The well known observation of Herodotus (¹) that Egypt was an acquired country and in fact that it was the gift of the river was commented on by Henry Drummond (²) in describing the activities of termites. The fresh soil prepared and brought to the surface by these insects is the first to be swept off by the rains and he suggested that the fertility of the Nile deposits might be partly due to this cause.

The origin and nature of the soil of the Abyssinian plateau have been described in the earlier part of this chapter. As soon as these are seen, the nature of the red water of the

(¹) History of Herodotus, Euterpe, 5.
(²) " Tropical Africa," 4th edition, London, 1891, Chapter VI

Nile flood is clear and it is soon brought home to the traveller who has to negotiate the turbid waters of many small streams, all of the colour of cocoa without milk. The water, even of storms, has little effect on a great deal of the surface, which is protected by vegetation, but where it collects and passes along a beaten track, quantities of the bright red soil are carried off and this is added to material torn from the sides of small streams. The influence of the discharge of such a stream as the Chimbil in making the whole of the Blue Nile turbid just below the outlet has been referred to. There are white ants on the plateau, but they only deal with an almost negligible proportion of the soil carried away by the rain, and it can be concluded that the great bulk of the fine red clay which colours the water of the Nile flood is derived directly from soils formed by the decomposition of basalts.

CHAPTER V.—HYDROLOGY.

Gauges.

On July 29, a gauge known as the Rocks gauge was established on the lake in a small bay just east of Bahrdar Giorgis village. On August 1, a gauge known as Kamforo gauge was established on the Blue Nile at Kamforo ferry. Owing to the rise in water levels, the Rocks gauge became difficult of access, and on August 9 the Fig Tree gauge was established in the same vicinity close to a large tree about a kilometre east of the village. On August 17, readings were begun at a point known as the Ifwadda gauge at the south end of Ifwadda Lagoon and gauges were established at the discharge sites at Burifasas and Egirrbar.

It was impossible to fix scales at these various places, consequently, for the purpose of observing the water levels, bench-marks were established at each of the gauges. The observations were made by measuring the depth of water on rock points selected in succession with regard to their shape and stability as the water rose or fell.

The following gauges were read every morning and whenever possible during the day.

The Fig Tree.
Ifwadda.
Kamforo.

The routine was carried out by an observer who started from the camp soon after dawn and passed along the track by the Fig Tree and Ifwadda to Kamforo. He returned by the same route and again read the two gauges. This gave two readings of the Fig Tree gauge with an interval of rather more than an hour and two readings at Ifwadda with an interval of about 20 minutes. The readings at these intervals proved very useful in indicating the extent to which the lake was disturbed by seiches. At the time of the highest water levels, when it was desired to obtain a definite value of the lake level to which to refer discharge measurements, an observer was posted to read the Fig Tree gauge at 10-minute intervals at times corresponding to the discharge observations. Diagram 9 shows the results of readings at the three gauges.

The seiche makes it impossible to assign a definite level to the water on any particular day without taking a large number of readings. Accordingly five-day means have been computed from all the readings; these are given below in Table IV, and the level on any particular day can be found from this table.

TABLE IV.—LAKE AND RIVER GAUGES, REDUCED LEVELS (FIVE-DAY MEANS).

PERIOD 1920–1921.	LAKE.		RIVER.
	Fig Tree Gauge.	Ifwadda Gauge.	Kamforo Gauge.
July 29–31...	79·99	—	—
Aug. 1– 5...	80·09	—	77·07
6–10...	·20	—	·21
11–15...	·30	—	·33
16–20...	·45	80·45	·54
21–25...	·58	·58	·74
26–31...	·71	·69	·93

TABLE IV (*continued*).

Period 1920–1921.	Lake.		River.
	Fig Tree Gauge.	Ifwadda Gauge.	Kamforo Gauge.
Sept. 1–5	80·75	80·72	78·02
6–10	·77	·78	·05
11–15	·82	·81	·11
16–20	·88	·88	·21
21–25	·92	·92	·29
26–30	·94	·92	·29
Oct. 1–5	·95	·95	·33
6–10	·94	·95	·29
11–15	·93	·93	·26
16–20	·91	·90	·23
21–25	·87	·86	·17
26–31	·81	·81	·07
Nov. 1–5	·78	·77	77·99
6–10	·73	·72	·94
11–15	·68	·67	·86
16–20	·63	·64	·80
21–25	·62	·61	·74
26–30	·56	·54	·69
Dec. 1–5	·52	·50	·63
6–10	·48	·48	·57
11–15	·45	·43	·52
16–20	·41	·40	·47
21–25	·38	·37	·42
26–31	·33	·31	·36
Jan. 1–5	·30	·27	·32
6–10	·27	·26	·28
11–15	·24	·23	·24
16–20	·21	·20	·21
21–25	·19	·17	·17
26–31	·16	·16	·14
Febr. 1–5	·12	·11	·09
6–10	·10	·09	·05
11–15	·06	·05	·02
16–20	·02	·02	76·99
21–25	79·99	79·98	·96
26–28	·98	·97	·94
March 1–5	·97	·98	·92
6–10	·94	·94	·91
11–15	·91	·91	·88
16–20	·89	·88	·86
21–25	·85	·84	·82
26–31	·82	·81	·78
April 1–5	·79	·78	·75
6–10	·75	·73	·72
11–15	·73	·72	·70
16–20	·69	·66	·67
21–25	·64	·63	·65
26–30	·63	·61	·63
May 1–5	·57	·59	·61
6–10	·56	·57	·58
11–15	·53	·55	·57
16–20	·49	·50	·54
21–25	·49	—	·54
26–31	·47	—	·51

TABLE IV (*continued*).

Period 1920-1921.		Lake.		River.
		Fig Tree Gauge.	Ifwadda Gauge.	Kamforo Gauge
June	1– 5...	79·43	—	76·50
	6–10...	·39	—	·48
	11–15...	·40	—	·48
	16–20...	·43	—	·48
	21–25...	·40	—	·47
	26–30...	·43	—	·48
July	1– 5...	·45	—	·50
	6–10...	·46	—	·51
	11–15...	·52	—	·54
	16–20...	·55	—	·61
	21–25...	·69	—	·68
	26–31...	·82	—	·83

Readings after May 24, 1921, supplied by Mr. J. R. Herbert.

Discharge Observations at the Outlet of Lake Tana.

The First Discharges.

On arrival at the outlet of the lake, work was begun at once. A visit to Kamforo ferry yielding no prospect of a suitable site and no *tankwa* being immediately available to explore the river, a visit was made to Egirrbar ford, about 9 kilometres down the river, where Mr. Dupuis measured his discharge in January 1903. Here a suitable site was found and discharges were taken on August 1 and the three following days. A three-quarter inch circumference wire rope was stretched across the river and velocity stations were fixed by box sextant observations from the west bank. The surface width at the discharge site was about 110 metres, mean depth 0·9 metres and mean velocity 0·8 metres a second. As the native staff was new to the work and the rope had to be stretched afresh each day, these first four discharges were each a full day's work.

The Low Stage Discharge Site at Egirrbar.

On August 4, the work had to be temporarily suspended for a week owing to the objections of some chiefs, and the opportunity was taken during this time to explore the river from the lake outlet to a point 10 kilometres downstream. The course is very irregular and the river consists of a series of ponds and rapids. It was found that Egirrbar ford was the only suitable place for a discharge site at low stage. The earliest discharges were taken on a line referred to as Egirrbar I, a few metres upstream of Egirrbar III, indicated in Photograph 5 (taken on April 12). As the river was then rising steadily it was seen that this locality would soon become unsuitable for discharge work from a *tankwa*

and the operations were moved to Burifasas. On January 8 the river had diminished to such an extent that the velocities at Burifasas were no longer satisfactory and a return was made to Egirrbar II, a site upstream of the others and appearing about 2 centimetres from the right-hand margin of Photograph 5. This clearly shows, nearly parallel to the west bank, a rapid which interfered with discharge observations as the stream fell and the current across the bar became more pronounced. Recourse was then had to Egirrbar III, indicated by dashes on the photograph, where the discharge *tankwa* appears as a faint dot towards the right hand side of the stream. As the river fell, the water became very shallow and there were belts along either bank where there was hardly enough depth to allow the current meter to be submerged. This was dealt with by building out small banks, thus cutting off the shallower parts of the section, which were also unsatisfactory owing to eddies among boulders. The conditions at the lowest stage cannot be regarded as entirely satisfactory, but the volume of the river is then so small that even a considerable proportion of error is of little practical importance as regards the study of the hydrography of the lake. Section 5 (2) and (3) shows the discharge sites at Egirrbar II and III. The east bank is on the right of the section.

The Flood Discharge Site at Burifasas.

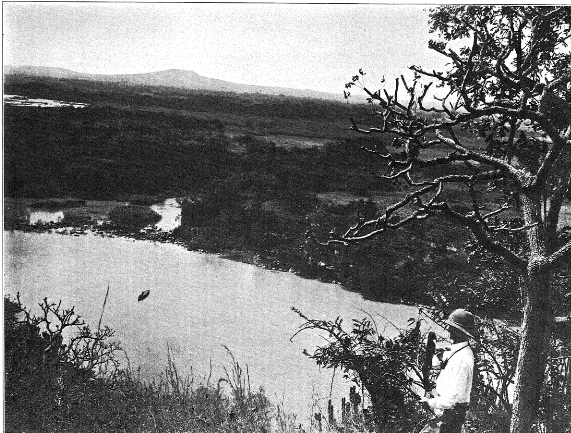
The only promising place on the river for a flood discharge site was the Burifasas reach, about 7 kilometres from the outlet, and this was adopted when work was resumed on August 12. The site is shown in Photograph 19 and in (1) Section 5. Here the mean velocity was at first about 0·3 metres a second but rose to 1 metre a second at the top of the flood. The width of the section was about 115 metres.

Subsequent investigation failed to reveal any other site suitable for observing discharges during flood. A site at Kamforo ferry had been suggested but the section proved to have far too great an area, with reverse currents due to cataracts immediately upstream. The low velocities here are demonstrated in Photograph 7*a*, showing an old and almost sodden *tankwa* being propelled across on September 22, at nearly the highest stage of the flood. The depth of water below the *tankwa* was about 10 metres and the pole was being used merely as a paddle.

Equipment.

The ¾-inch circumference galvanized iron wire rope was stretched over 120 metres at the camp and graduated in 4-metre lengths, the graduations being painted with white enamel. It was then taken to Burifasas and stretched double across the discharge site, the upstream part being 15 metres from the actual discharge section, so as to provide the upper end of the base for float observations. As the variation of water level at Burifasas throughout the season was only 60 centimetres, no difficulty was experienced in keeping the rope stretched clear of the water all the time. This size of rope was found to be most satisfactory for the work, as it could be stretched across 200 metres of water without any trouble. Later, when it was required for survey work on the river, it was replaced at Burifasas by 1-inch circumference rope, which was stretched by means of pulley blocks and tackle.

A 10-kilogramme sounding weight was found to be quite heavy enough. The arrangement of the discharge *tankwa* is shown in Photograph 20. A 2-metre ranging rod with



No. 19.—Burifasas Discharge Site from Hill.



No. 20.—Atto Tasfai on the Discharge Tankwa.

a pulley was fixed on either side to facilitate the raising and lowering of the sounding weight and current meter. Two small Gurley current meters of the Price or bucket pattern were employed being used on alternate days so as to detect any change in the rating.

Method of Observation.

Two men were necessary to manage the boat, one to manœuvre it along the rope from station to station and the other to act as a counterpoise and to raise and lower either the sounding weight or current meter when required. Soundings were taken at each of the 25 stations across the section, the current meter was then immersed to half-depth and the number of revolutions in 3 minutes noted. The number of revolutions in each minute was also noted and any wide discrepancy among them investigated on the spot. At high stage, with a surface velocity of 1·5 metres a second, some skill was needed in managing the boat. However, two of the staff became so expert at this work that discharges were taken right through the season without a hitch. The river bed being very rough, the sounding weight sometimes slipped into crevices between boulders and could only be dislodged by divers.

Float Observations.

After each discharge, except on windy days, a series of observations was taken for maximum surface velocity. A base of 30 metres was laid out half upstream and half downstream of the section, the upper wire rope already mentioned forming the upstream end, and the time of passage of a number of surface floats over this base was noted by stop watch. The floats consisted of two pieces of light wood 10 centimetres long bound together in the form of a cross with a short upright piece in the centre on which was placed a small piece of paper for observation purposes. The floats were dropped in by the observer from the *tankwa* in mid-stream and their time of passing the lower end of the base signalled by another observer stationed on the bank opposite that point.

Much credit is due to George Eff. Yanni Karkanis for his work in connection with discharges. The work was quite new to him, but after a little instruction, supervision, and practice, he became a first class observer and carried out all the observations from February 25 to May 24, 1921, as well as several at the top of the flood. Credit is also due to Haile Eff. Kibret, the interpreter, who undertook gauge reading during the discharge observations and assisted with the observation of the floats.

Computation of Discharges.

The computations of the discharges have all been made on the basis of the tables derived from the Physical Department ratings of the current meters in April 1920, to which reference will be made hereafter. The mean velocity in the vertical is taken to be 96 per cent of the half-depth velocity.

No corrections to current meter volumes have been made either on account of turbulence or of seiche. Turbulence, though always apparent to the eye in the form of small eddies, was small in comparison with that observed on the Main Nile at Cairo, and any correction due to seiche affects only the gauge-discharge curve and does not affect the total discharge from the lake. The results are given in Table V.

Discharge Curves.

(*a*) *Time-Discharge Curve.*—A time-discharge curve, Diagram 6, has been plotted from August 1, 1920, to July 31, 1921, discharge observations after May 17, 1921, being taken by Mr. J. R. Herbert. On the same diagram is plotted a curve showing total discharge of the lake from August 1, 1920, up to any date to July 31, 1921, and from this it is seen that the total discharge of the lake during the year was 3,460 million cubic metres.

(*b*) *Gauge-Discharge Curves.*—Three gauge-discharge diagrams have been drawn showing :—

(1) Discharge and the Fig Tree gauge, Diagram 7.
(2) Discharge and Kamforo gauge „ 7.
(3) Discharge and Burifasas gauge „ 10.

All gauge readings are reduced levels and those on (1) and (2) are taken from a five-day mean curve for the day of the corresponding discharge.

Three small streams enter the river between the lake outlet and Burifasas discharge site, but the only one of any importance is the Chimbil, which enters above Kamforo and might contribute 10 cubic metres a second during a flush. It may be noted that for this reason the points lie closer to the curve at the top of the flood on (2) than on (1). The difference on the gauge-discharge curve between the rising and falling stages is explained by the fact that, as the lake falls, the cataracts at the outlet are covered with weeds and a similar condition obtains at all the rapids down the river. These weeds have the effect of raising the cataract sill and increasing the friction, both of which factors cause a diminution of discharge for the same lake level. It is to be noted that, as the lake outlet and river bed are both rock, the relation of the discharge to level (except for variation in the incidence of the cataract weed) is constant from year to year. Thus the gauge-discharge curves (1), (2) and (3) may be used for any year within the limits for which observations exist.

Current Meter Rating.

After use the current meters were always stripped, cleaned and oiled before being put away, and no discrepancy between the two ever appeared. After they had been in continuous use for a month, it was decided to rate them, and this was done on five occasions during the season. For rating purposes a small bay, shown in Photograph 21, was chosen just east of the Fig Tree gauge. The shore of the lake is so rough and thickly wooded that it was decided to have the rating base over water. Accordingly, a ⅜-inch circumference wire rope was stretched and a 50-metre base marked out on it, 3 metres being graduated in 10-centimetre lengths at either end. The rope was then stretched across the bay from a small island about 100 metres from the lake shore. The current meter was suspended from the front of a *tankwa* in exactly the same manner as in discharge observations and 60 centimetres below the water surface Hemp ropes were attached to either end of the *tankwa* to enable it to be towed along the base in both directions. The observer sat in the front with a man at the back to act as a counterpoise, and the *tankwa* was kept parallel to the base by both allowing the wire rope to run through their fingers. To determine the base length of an exact number of revolutions, small cotton bows were



No. 21.—Current Meter Rating.

lightly tied on to the wire at either end of the base. These were moved along the rope by the observer's fingers, one being released to mark the beginning of a run and the other the end. In this way it was possible to read the base length to single centimetres. After some experience of this work, it was found that an old and water-logged tankwa was much better than a new one, as it responded less to wave motion on the lake. This is a point of some importance, as any motion produces rotation of a Gurley current meter. After the observations had been completed, the base rope was taken down, restretched at the camp and a correction made for any increase in length found.

The ratings at the lake never differed by more than 1 per cent from the initial Physical Department rating at Gîza, being slightly above this and nearer to the maker's rating at high velocities. On return to Cairo, the current meters were again rated at Gîza by the Physical Department both as received and after cleaning. The ratings before and after cleaning were exactly the same. Diagrams 8*a* and 8*b* show the initial and final ratings of the Physical Department at Gîza and the Lake Tana ratings are shown as five series of points whose mean is as nearly as possible the initial Gîza rating. On the strength of this evidence the rating tables for the initial Gîza ratings have been used for the computation of all discharges.

In the summer of 1921, a new and improved method of current meter rating was adopted by the Physical Department. (1) On the new rating, discharges taken at Khannaq, a short distance downstream of Aswân Dam, are in close agreement with those taken through the sluices of the dam. A comparison of this new rating with the old Gîza rating shows that, at velocities of the order of those obtaining at Burifasas near the top of the flood, the Gîza rating should be increased by 2·5 per cent so as to correspond with the new rating. On the other hand, the coefficient for reducing half-depth velocity to mean velocity, as determined by experiment on the actual discharge site at Burifasas, is 0·92 (*see* Appendix iii to present chapter) or 4 per cent less than the coefficient actually used in the computation of the discharges. The net result therefore of using the 0·96 coefficient and the Gîza ratings of the current meters is to make the discharges 1·5 per cent too high. This proportion is rather less than the probable error of the individual discharges.

TABLE V.—LAKE TANA DISCHARGES.

August 1, 1920-July 31, 1921.

DATE.		Lake Level.	River Level.	Discharge.	SITE	Area of Section.	Mean Velocity.	Maximum Surface Velocity.	M.V. / M.S.V.
1920.		Fig Tree Gauge.	Kamforo Gauge.	Cubic M. per Second.		Square Metres.	Metres per Second.	Metres per Second.	
August	1	80·05	77·02	76·7	Egirrbar I.	87·4	0·878	—	—
	2	·08	·05	75·9	,,	96·4	·787	—	—
	3	·10	·08	76·0	,,	95·7	·794	—	—
	4	·12	·11	81·4	,,	99·0	·822	—	—
	12	·29	·32	99·3	Burifasas	291·3	·341	—	—
	13	·32	·34	110·2	,,	291·7	·378	—	—
	16	·41	·46	131·0	,,	301·3	·435	—	—

(1) Physical Department Paper No. 14, 1924.

TABLE V (*continued*).

Date.	Lake Level.	River Level.	Discharge.	Site.	Area of Section.	Mean Velocity.	Maximum Surface Velocity.	M. V. / M.S.V.
1920.	Fig Tree Gauge.	Kamforo Gauge.	Cubic M. per Second.		Square Metres.	Metres per Second.	Metres per Second.	
August 18	80·47	77·55	153·2	Burifasas	306·1	0·500	—	—
20	·52	·64	161·2	,,	308·8	·522	0·78	0·67
21	·55	·69	166·5	,,	311·6	·534	·79	·68
24	·63	·80	193·8	,,	319·1	·607	·86	·71
26	·67	·87	215·6	,,	320·0	·674	·95	·71
27	·69	·90	216·0	,,	322·8	·669	·96	·70
28	·71	·93	223·6	,,	323·1	·692	·93	·74
31	·74	·98	244·4	,,	336·1	·727	·98	·74
Sept. 3	·76	78·02	244·8	,,	338·2	·724	1·06	·68
6	·76	·05	267·8	,,	339·4	·789	—	—
7	·77	·06	267·5	,,	340·8	·785	1·07	·73
11	·80	·09	272·2	,,	342·5	·795	—	—
13	·82	·12	284·1	,,	348·8	·814	—	—
16	·86	·18	291·6	,,	348·2	·842	1·22	·69
18	·88	·22	307·9	,,	351·1	·877	1·22	·72
20	·90	·26	326·1	,,	353·9	·921	1·25	·74
21	·91	·28	338·1	,,	358·8	·942	1·27	·74
23	·92	·29	333·7	,,	355·4	·939	1·31	·72
24	·92	·29	337·1	,,	358·7	·940	1·32	·71
25	·93	·29	339·3	,,	359·8	·943	1·27	·74
27	·94	·29	334·1	,,	358·1	·933	1·31	·71
28	·94	·29	329·1	,,	357·6	·920	1·32	·70
29	·94	·30	332·7	,,	358·8	·927	1·29	·72
30	·94	·31	337·2	,,	360·0	·936	1·38	·68
October 1	·95	·32	336·4	,,	359·0	·937	1·28	·73
2	·95	·33	347·7	,,	362·9	·958	1·31	·73
4	·95	·32	342·6	,,	360·0	·952	1·34	·71
5	·94	·31	336·2	,,	360·1	·934	1·32	·71
6	·94	·30	333·5	,,	359·1	·929	1·30	·71
7	·94	·30	333·3	,,	357·0	·934	1·23	·76
9	·94	·28	324·7	,,	358·1	·907	—	—
12	·93	·26	322·0	,,	355·2	·906	1·30	·70
16	·91	·24	319·9	,,	352·9	·907	1·19	·76
20	·89	·20	309·2	,,	352·4	·878	1·23	·71
23	·86	·16	294·3	,,	350·2	·840	1·13	·74
27	·82	·08	278·2	,,	343·5	·810	—	—
30	·80	·04	259·2	,,	341·7	·759	—	—
Nov. 2	·78	77·99	254·7	,,	336·4	·757	—	—
5	·76	·96	241·8	,,	338·3	·715	1·03	·69
9	·71	·91	236·3	,,	337·9	·699	—	—
13	·68	·85	217·7	,,	334·4	·651	0·92	·71
17	·63	·80	202·2	,,	327·5	·614	·93	·66
20	·62	·77	193·3	,,	322·4	·599	·87	·69
25	·59	·71	177·1	,,	320·9	·552	—	—
30	·54	·65	167·2	,,	317·4	·527	—	—
Dec. 4	·51	·61	154·4	,,	316·5	·488	·63	·77
9	·47	·56	144·5	,,	308·7	·468	—	—
14	·44	·50	137·3	,,	307·8	·446	·66	·68
18	·40	·46	127·5	,,	307·2	·415	—	—
23	·37	·41	116·4	,,	301·3	·386	·61	·63
28	·33	·36	112·0	,,	299·3	·374	—	—

TABLE V (*continued*).

DATE.	Lake Level.	River Level.	Discharge.	SITE.	Area of Section	Mean Velocity.	Maximum Surface Velocity.	M.V. / M.S.V.
1921.	Fig Tree Gauge.	Kamforo Gauge.	Cubic M. per Second.		Square Metres.	Metres per Second.	Metres per Second.	
January 3	80·30	77·31	98·1	Burifasas.	294·3	0·333	0·52	0·64
8	·27	·28	96·3	Egirrbar II.	125·8	·765	1·18	·65
13	·24	·24	91·3	„	120·5	·758	—	—
18	·21	·21	82·7	„	115·1	·719	—	—
22	·19	·17	79·7	„	111·5	·715	—	—
27	·16	·14	75·2	„	108·7	·691	1·02	·68
February 2	·12	·10	66·7	„	102·2	·652	0·98	·67
9	·08	·04	58·7	„	96·5	·608	·90	·68
16	·02	·00	50·1	„	92·5	·542	·83	·65
23	79·98	76·96	46·6	„	86·4	·539	·70	·77
28	·97	·94	43·7	„	81·8	·534	·81	·66
March 5	·95	·92	39·4	„	80·4	·490	·80	·61
10	·92	·90	39·6	„	79·4	·498	·75	·66
15	·90	·87	34·7	„	74·4	·467	·81	·58
22	·84	·82	32·8	Egirrbar III.	54·8	·599	—	—
29	·81	·77	26·4	„	48·0	·549	—	—
April 5	·77	·74	23·6	„	42·7	·552	1·00	·55
12	·73	·70	19·6	„	36·7	·534	0·96	·56
19	·67	·66	15·4	„	33·8	·456	·91	·50
26	·63	·64	13·4	„	30·9	·434	·80	·54
May 3	·57	·61	11·0	„	28·8	·381	·79	·48
10	·54	·58	8·6	„	26·4	·328	·73	·45
17	·49	·54	7·5	„	24·2	·310	·68	·46
24	·50	·54	6·1	„	24·9	·246	—	—
31	·46	·50	5·4	„	20·6	·261	—	—
June 7	·41	·48	5·5	„	20·9	·265	—	—
14	·41	·48	4·8	„	20·2	·239	—	—
21	·40	·47	4·1	„	19·0	·214	—	—
28	·43	·48	6·3	„	20·6	·257	—	—
July 5	·45	·50	6·5	„	22·8	·284	—	—
12	·48	·53	7·6	„	23·6	·322	—	—
19	·58	·63	14·6	„	32·4	·452	—	—
26	·75	·76	24·2	„	43·0	·561	—	—
30	·88	·89	37·0	„	58·9	·629	—	—
August 1	·97	·96	54·6	„	83·2	·657	—	—

Discharges from May 24 to August 1, 1921, taken by Mr. J. R. Herbert.

Lake and River levels are taken from a five-day mean curve for the day of the corresponding discharge.

TABLE VI.—MONTHLY TOTALS AND MEAN DISCHARGES.
(1920–1921.)

MONTH.	Monthly Mean Discharge. Cubic Metres per Second.	Monthly Total Discharge. Millions of Cubic Metres.
August	143	383
September	297	771
October	310	831
November	209	542
December	132	354
January	86	231
February	54	130
March	35	94
April	18	46
May...	8	22
June	5	13
July...	15	41
		TOTAL ... 3,458

TABLE VII.—ACCUMULATED DISCHARGE OF LAKE TANA FROM JULY 8.

(In Millions of Cubic Metres.)

DATE.		Accumulated Discharge.	DATE.		Accumulated Discharge.	DATE.		Accumulated Discharge.
July	8	0	December	5	2,634	May	5	3,425
	10	2		10	2,697		10	3,429
	15	6		15	2,757		15	3,433
	20	12		20	2,812		20	3,436
	25	21		25	2,862		25	3,439
	31	38		31	2,919		31	3,442
August	5	72	January	5	2,962	June	5	3,444
	10	112		10	3,004		10	3,446
	15	160		15	3,043		15	3,449
	20	223		20	3,079		20	3,450
	25	304		25	3,112		25	3,452
	31	421		31	3,150		30	3,455
September	5	530	February	5	3,178	July	5	3,457
	10	645		10	3,204		10	3,460
	15	768		15	3,227		15	3,464
	20	902		20	3,248		20	3,470
	25	1,047		25	3,268		25	3,479
	30	1,192		28	3,280		31	3,496
October	5	1,339	March	5	3,298			
	10	1,481		10	3,315			
	15	1,620		15	3,331			
	20	1,755		20	3,346			
	25	1,882		25	3,359			
	31	2,023		31	3,374			
November	5	2,131	April	5	3,384			
	10	2,232		10	3,394			
	15	2,325		15	3,402			
	20	2,412		20	3,409			
	25	2,491		25	3,415			
	30	2,565		30	3,420			



No. 23.—Chara Chara Cataract, on May 21, 1921.



No. 22.—Chara Chara Cataract, on September 29, 1920.

Relative Size of the 1920 Flood.

In 1920, at the highest stage of the lake, many trees along the shore had their roots submerged and stood with the water around their stems. Some overhanging branches of large trees dipped into the water and certainly would not have withstood immersion long, as was shown by the decayed ends of other branches at about the same levels. The large Fig Tree at the lake gauge had a water beaten appearance at the base of the trunk just above the highest flood level, also suggesting that as a rule the lake does not rise much higher. Similar conditions occurred along the river, the bases of trees were awash and the flood had reached the back of papyrus swamps. During the time of the highest levels, particularly when the water was rising, the surface of the stream was covered with debris of papyrus and marsh plants that had been dislodged. All these things suggest that the flood of 1920 was well up to the average level and that the water does not as a rule rise much higher. The general opinion of the people seemed to be that the flood was fair or perhaps a little below normal.

The level of the flood of 1915 can be inferred with some confidence from Mr. Buckley's record of the level of the top of the white belt described in Chapter IV. In 1920, the top of the white belt was at 80·92 metres and the flood level 3 centimetres higher. Assuming a similar difference in 1915, the flood level of that year can be assumed to be 80·97. Mr. Dupuis has not specially recorded the level of the top of the white belt, but he states, as a result of many observations and enquiries, that the level reached by the flood of 1902 was about 75 centimetres above the water level at the end of January. The discharge measured by Mr. Dupuis enables this statement to be correlated with our levels. The measurement was made with a current meter on January 31, 1903, when 42 cubic metres a second was found to be passing down the river. Assuming that the gauge-discharge relations were the same as in 1921, this corresponds to a lake level of 79·96. In order to obtain confirmatory evidence very careful observations were made at Chara Chara, which was photographed by Mr. Dupuis at about the time of his measurement.(1) It was found that so little change had occurred during the intervening years that nearly all the boulders shown in Mr. Dupuis' picture could be identified. The lake was at 79·96 on March 3, 1921, and a photograph taken on February 28 shows slightly more water, while another taken on March 5 shows distinctly less water than does Mr. Dupuis' photograph. There can be no question therefore of the perfect correctness of Mr. Dupuis' measurement or that it corresponded very closely to a level of 79·96. This suggests that the flood level was between 80·70 and 80·75. Probably it was nearer the latter, having regard for the fact that the flood rises a few centimetres above the limit of the white belt. Mr. Herbert has recorded the levels of the floods of 1921 and 1922 and found that the lake reached 80·98 and 81·15 respectively.

Information from the inhabitants regarding the levels reached by floods and the time of their occurrence was found to be very conflicting and quite untrustworthy. The difference in level between an average flood and a very high one can only be about 40 centimetres, and this hardly concerns the inhabitants, who have no interest along the shores, especially as the whole country at the time is still sodden as a result of the rains. Fordability of the river is the only feature that directly affects the daily life of the people and it seems to be the one relating to the lake on which their information is likely to be

(1) Plate XLI, photo. entitled "River Abai, First Rapid, where it leaves the Lake," *loc. cit.*

most reliable. There are three fords near Bahrdar Giorgis. The nearest to the lake is at Kamforo just upstream of the ferry. Another at Burifasas takes advantage of the sill of a cataract where the river is very wide. The third is at Egirrbar and is probably the easiest of the three. On our arrival at the lake at the end of July 1920, people were still fording, but the river became unfordable within a very few days. It was then fordable at Egirrbar when the lake level was below 80·12 and it may have been forded with difficulty at 80·15. The exact limit is impossible to define, since strong tall men must be able to ford the river at higher levels than other people. After the flood the lake fell to 80·12 on February 3. A wire rope was stretched across at Egirrbar on January 6, and people began to wade across soon afterwards with support from it and up to their necks in water. Towards the end of January, when the lake was approaching 80·12, the ford became easier and on market days both men and women crossed, pushing bundles of papyrus bearing their chattels. Donkeys were able to ford on about February 20, and after February 24 there was no further difficulty. When the lake fell to 79·90 people crossed with the water only to their waists.

At Kamforo a man was seen crossing on February 20, but he had taken off all his clothes and wrapped them round his head to keep them out of water. This ford may be regarded as having become practicable from March 1, when more people were seen crossing and the passage was evidently easier. The ford at Burifasas was not under observation, but it was said to have been crossed on foot in January. In 1916 it was easily crossed by mules at some time when the lake level was between 80·00 and 79·91, probably nearer the latter. Mr. Buckley's records in 1916 show that 79·96 was reached on March 2, almost the same date as in 1921, so that the falling stages of these two years can be regarded as practically identical. The level 80·12, when the river became fordable, occurred a month before 79·96 in 1921, and presuming that the lake was falling at a similar rate in 1903, it can be said that the river became fordable at the beginning of January. This is an unusually early date for the river to become fordable and it bears out the conclusion reached by Mr. Dupuis, as a result of other lines of reasoning, that the flood at Lake Tana in 1902 was a relatively small one. During the interval of thirty-three days between Mr. Dupuis' visits to Delgi the level of the lake fell 15 centimetres approximately from 80·06 to 79·91, and it is interesting to note that this fall occurred in 1921 between February 13 and March 13, or almost a similar period. Turning now to local information, questions were asked about fordability in relation to certain festivals. January 19 is the Baptist's day, St. George's day is January 26, and St. Mary's day is January 29. An intelligent chief remarked that if the rain stopped early and fine and cloudless weather prevailed the lake dropped early and the river might be fordable on the Baptist's day. He went on to relate that if fine weather continued and the rains were late the lake fell very low and the river became very small. The priests at Bahrdar Giorgis agreed that the river was usually very difficult to ford in January.

The influence of the flood on the following low stage depends, as the old chief pointed out, on several conditions and the levels will continue high if the crest of the flood is high and late, while an early high flood may be followed by normal levels. It seems probable that high levels during the low stage may affect those of the succeeding flood, since the lake will begin filling from a higher level and attain a correspondingly greater height.

Tabulating the information, it is as follows :—

Season.	Maximum.		Date of Lake discharging 42 Cubic Metres a Second.	Minimum.	
	Level.	Date.		Level.	Date.
1902–1903	80·75	—	January 31	—	—
1915–1916	80·97	—	March 2	—	—
1920–1921	80·95	October 1	March 3	79·39	June 8
1921–1922	80·98	September 28	February 24	79·39	June 12
1922–1923	81·15	September 18	March 8	79·55	June 28
1923–1924	81·21	September 25	March 15	—	—

Addis Abbaba is the nearest place for which rainfall statistics during these years are available, but it appears to be too far away to permit of correlation. The figures are as follows :—

Year 1902 ... ... 1,152 millimetres.
„ 1915 ... ... 1,900 „
„ 1920 ... ... 1,077 „
„ 1921 ... ... 1,041 „
„ 1922 ... ... 1,060 „

No profitable result seems likely from an attempt to compare flood levels at Lake Tana with those attained on the rivers. The level at the lake depends on the whole volume discharged into it and not merely on the maximum rate on a particular date. The total discharge of the Blue Nile at Soba in 1915-1916 was about 40 milliards of cubic metres and in 1920–1921, 47 milliards, a difference of 15 per cent without any corresponding difference in the flood level of the lake. This appears to indicate a very small range in the variation of the lake's flood level. When it is possible to compare a large series of years, a relation may be found between the lake levels and the total volumes discharged by some of the rivers, such as the Atbara, the Rahad, or the Dinder, which drain from the same region. Meanwhile, all the evidence suggests that the flood of 1920 reached an average height and consequently the figures can be adopted as a good basis of discussion.

Estimated Sizes of High and Low Floods.

The evidence for adopting 81·30 as the level of a very high flood has been given in Chapter IV and it appears that such a level can only rarely and very slightly be exceeded. At the other extreme 80·50 has been adopted as the maximum level of a very low flood. The limits 81·30 and 80·50 for very high and very low floods respectively are put forward with reserve, as merely estimates. It is unfortunate that the years during which the levels of the lake have been observed have not been very dissimilar on the Blue Nile.

The discharges of Lake Tana in a very low year and also in a very high year, on the basis of the levels just adopted, have been computed from assumed gauge curves and with

extrapolation from the gauge-discharge curve of 1920–1921 and the results for the months during which storage may take place are given below in Table VIII :—

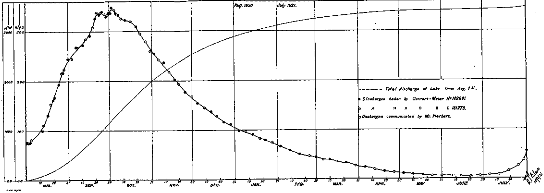
TABLE VIII.—ESTIMATED DISCHARGES OF LAKE TANA IN A VERY LOW AND A VERY HIGH YEAR RESPECTIVELY.

Computed from estimated Gauge Curve and Gauge-Discharge Curve of 1920-1921 with Extrapolation.

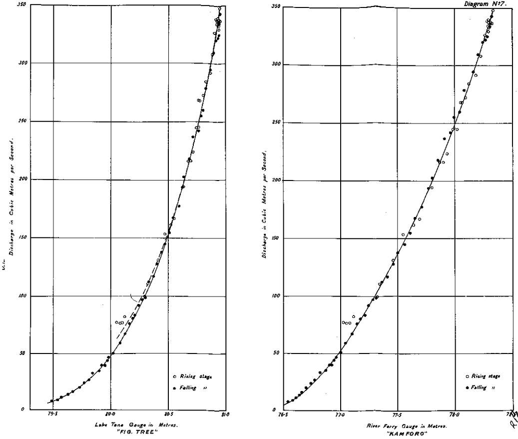
Tana Calendar.		Very Low Year.			Very High Year.		
		Gauge.	Discharge.		Gauge.	Discharge.	
			Cubic Metres per Second.	Monthly Totals. Millions of Cubic Metres.		Cubic Metres per Second.	Monthly Totals. Millions of Cubic Metres.
July	8–10	79·47	7		79·47	7	
	11–20	63	14		·64	15	
	21–31	87	33	45	·93	40	53
August	1–10	80·06	64		80·23	92	
	11–20	·21	88		·53	165	
	21–31	·32	110	236	·82	277	485
September	1–10	·41	132		81·08	426	
	11–20	·46	146		·23	517	
	21–30	·50	156	375	·29	553	1,293
October	1–10	·49	151		·29	553	
	11–20	·47	145		·23	517	
	21–31	·43	133	382	·14	462	1,364
November	1–10	·38	120		·02	390	
	11–20	·32	106		80·92	330	
	21–30	·25	90	273	·82	277	861
December	1–10	·19	79		·72	233	
	11–20	·13	68		·63	198	
	21–31	·06	57	181	·54	167	531
January	1–10	80·00	48		·45	139	
	11–20	79·95	42		·37	117	
	21–31	·90	36	112	·30	101	317
			TOTAL ...	1,604		TOTAL ...	4,904

Diagram No. 6.

TIME DISCHARGE DIAGRAM



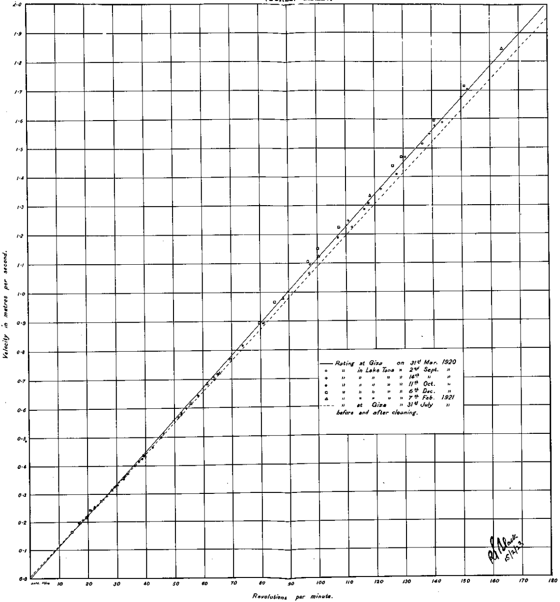
GAUGE DISCHARGE CURVES
FOR LAKE TANA



Datum: KAMFORO FERRY Bench Mark (R.L. 79.109)

CURRENT-METER Nº 182001
(GURLEY SMALL).

Diagram Nº 8 a.

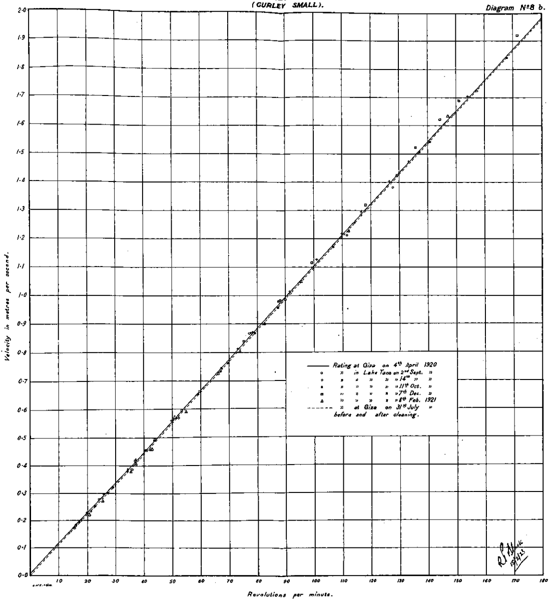


CURRENT-METER RATING

CURRENT-METER Nº 181278.

(GURLEY SMALL).

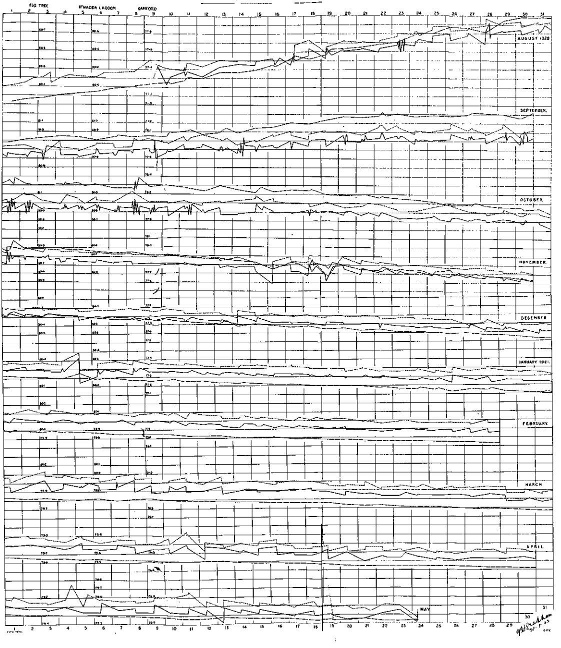
Diagram Nº 8 b.



DAILY WATER LEVELS

FIG TREE, IFWADDA AND KAMFORO GAUGES.

DIAGRAM Nº 9.



Appendix to Chapter V.

(i) Effect of Seiches on the Gauge-Discharge Relation.

Let D = Discharge.
h = Mean head of water on the cataract sill.
a = Amplitude of the seiche.

Assuming that the seiche can be represented by a simple harmonic function of the time, then the head of water on the sill at any time may be written as

$$h+a \cos pt$$

$$\begin{aligned} D &= f\,(h+a \cos pt) \\ &= f\,(h)+a \cos pt\, f'\,(h) + \frac{a^2}{1 \cdot 2} \cos pt\, f''\,(h) + \ldots \\ &= f\,(h)+a \cos pt\, f'\,(h) \text{ neglecting squares and higher powers of } a \end{aligned}$$

Mean value of D during an interval t_1 to t_2 may then be written

$$f\,(h) + \frac{a\,f'\,(h)}{t_2-t_1} \int_{t_1}^{t_2} \cos pt\, dt = f\,(h) + \frac{a\,f'\,(h)}{t_2-t_1} \cdot \frac{\sin pt_2 - \sin pt_1}{p}$$

Thus if a discharge is measured during the interval t_2-t_1, the increment of discharge due to seiche is $a\,f'\,(h)\,\dfrac{\sin pt_2 - \sin pt_1}{p\,(t_2-t_1)}$

Now the time taken to measure a discharge by current meter is never less than half the period of the seiche, so writing $t_2 - t_1 = \frac{\pi}{p}$ we get as the maximum increment of discharge due to seiche $\frac{2a}{\pi}\,f'\,(h)$, and the maximum percentage increment of discharge is $\frac{2a}{\pi}\,\frac{f'\,(h)}{f\,(h)} \cdot 100$

Assuming f of the form $k\,h^{3/2}$, this maximum percentage increment becomes $\frac{300}{\pi} \cdot \frac{a}{h}$

Taking the level of the cataract sill to be 79·40 and the amplitudes of a mean and of a large seiche to be 5 and 10 centimetres respectively we get:—

Lake Level.	Maximum Percentage Increment of Discharge due to Seiche.	
	For a Mean Seiche.	For a Large Seiche.
80·95	3	6
80·50	4·5	9
80·00	8	16

Generally, the period of a seiche is about three hours and the time occupied by a discharge about two hours or two-thirds of the period.

Putting $t_2 - t_1 = \frac{4}{3}\,\frac{\pi}{p}$, the increment of discharge becomes

$$\frac{3\,a \cdot f'(h)}{4\,\pi}\;2\cos\left(pt_1 + \frac{2\,\pi}{3}\right)\sin\frac{2\,\pi}{3}$$

of which the maximum is $\frac{3\sqrt{3}\,a}{4\,\pi}\,f'(h)$ and the maximum percentage increment

becomes $\frac{9\sqrt{3}}{8\,\pi}\cdot\frac{a}{h}\cdot 100 \doteq 60\,\frac{a}{h}$

For this case we get:—

Lake Level.	Maximum Percentage Increment of Discharge due to Seiche.	
	For a Mean Seiche.	For a Large Seiche.
80·95	2	4
80·50	2·75	5·5
80·00	5	10

From the actual lake levels and discharges we have:—

Lake Level.	Discharge.	Difference.
	Cubic Metres per Second.	
80·94 80·94	337·2 324·7	4 per cent.
80·76 80·76	244·8 267·5	9 „
80·63 80·63	202·2 193·3	4·5 „

(ii) Discharge Measurements by Means of Floats.

The following is an analysis of the float observations for maximum surface velocity at Burifasas discharge site and an investigation of the probable accuracy to be expected when discharges are taken by this method.

Immediately after each discharge by current meter, unless prevented by wind, a series of observations for maximum surface velocity of section was made. This was done by observing the time of travel of a surface float over a base of about 30 metres, half upstream and half downstream of the section, 15 to 20 observations going to each determination.

The ratio—mean velocity : maximum surface velocity—was thus determined throughout the season.

As the hydraulic depth of the section only varies between 2·6 and 3·1 metres, we may expect the above ratio to be a constant.

Let V_m = mean velocity of section.

V_s = maximum surface velocity of section.

So that V_m is determined by current meter and V_s determined by floats.

The effect of wind is to cause a daily systematic error in V_s and therefore in the ratio $V_m : V_s$ which we shall denote by the letter R.

The values of this ratio are therefore divided into three groups ;—

(1) No wind.

(2) Light N. wind increasing V_s and therefore diminishing the ratio $V_m : V_s$.

(3) Light S. wind diminishing V_s and therefore increasing the ratio $V_m : V_s$.

Group 1.	*Group 2.*	*Group 3.*
0·67	0·71	0·73
·68	·70	·72
·71	·68	·76
·74	·69	·74
·74	·74	·76
·72	·74	·77
·74	·72	
·73	·71	Mean ... 0·75
·73	·71	
·71	·70	
·71	·68	
·69	·71	
·64	·70	
	·71	
Mean ... 0·71	·70	
	·71	
	·71	
	·66	
	·69	
	·68	
	·63	
	Mean ... 0·70	

Assuming both systematic errors equal we get for this error ± 0·025 = ± 3·5 per cent.

Subtracting out this systematic error we get a new series of values of R.

R.	r	r^2
0·67	5	25
·68	4	16
·71	1	1
·74	2	4
·74	2	4
·72	0	0
·74	2	4
·73	1	1
·73	1	1
·71	1	1
·71	1	1
·69	3	9
·64	8	64
·73	1	1
·72	0	0
·70	2	4
·71	1	1
·76	4	16
·76	4	16
·74	2	4
·73	1	1
·73	1	1
·72	0	0
·70	2	4
·73	1	1
·72	0	0
·73	1	1
·73	1	1
·68	4	16
·71	1	1
·70	2	4
·65	7	49
·71	1	1
·70	2	4
·74	2	4
·72	0	0
·74	2	4
·75	3	9
Mean ... 0·72		$\Sigma r^2 = 274$

$$r = (\text{R} \sim \text{mean R})$$

$$\text{Probable error of mean} = 0\cdot674\sqrt{\frac{274}{38 \times 37}} = 0\cdot30.$$

$$= 0\cdot42 \text{ per cent.}$$

$$\text{Probable error of a single observation} = 0\cdot674\sqrt{\frac{274}{37}} = 1\cdot83$$

$$= 2\cdot5 \text{ per cent.}$$

The values of the sectional area at the discharge site have been plotted, Diagram 10, against the gauge readings. Up to R.L. 77·40 the width is constant. At this level there is a slight increase in width and above it the width is again constant. A mean straight line has been drawn through the points up to R.L. 77·40 and another through the points above this level. Taking the departures of the individual points from this mean line we get :—

Probable error of a single determination of area,

below R.L. 77·40=0·52 per cent.

above R.L. 77·40=0·31 per cent.

or 0·42 per cent say, throughout.

Probable error of mean, below R.L. 77·40=0·12 per cent.

" " " above " " =0·05 per cent.

or 0·1 per cent say, throughout.

Thus, the probable error of an area derived from the mean line and a gauge reading is 0·1 per cent.

Probable accidental error of $V_s = 1$ per cent.
(determined from the scatter of the time observations).

∴ Probable percentage accidental error of a discharge measured by maximum surface velocity, mean ratio 0·72 and sectional area from area gauge curve

$$=\sqrt{1^2 + (0{\cdot}1)^2 + (0{\cdot}42)^2}$$
$$=1{\cdot}1.$$

And since the probable error of R due to wind is 3·5 per cent, so also is the probable error of V_s and therefore the probable percentage error of the discharge due to wind is $\pm 3{\cdot}5$ $\begin{matrix} + \text{ for N. wind.} \\ - \text{ for S. wind.} \end{matrix}$

As a test of the reliability of the observations for R we may compute the probable error of the mean R from the probable error of an individual observation.

Taking A = area of section
D = discharge

$$\text{We have } V_m = \frac{D}{A}$$

$$\therefore P v_m = \sqrt{P_D^2 + P_A^2} \text{ when } P = \text{probable percentage error.}$$

Assuming probable error of a current meter discharge = 2 per cent

$$P v_m = \sqrt{2^2 + (0{\cdot}42)^2}$$
$$P v_s = 1$$

$$\therefore P\left(\frac{V_m}{V_s}\right) = \sqrt{2^2 + (0{\cdot}42)^2 + 1^2} = 2{\cdot}3.$$

∴ Probable percentage error of mean $\frac{V_m}{V} = \frac{2{\cdot}3}{\sqrt{38}} = 0{\cdot}35$, which compares favourably with the probable percentage error of 0·42 derived from the scatter of the values of $\frac{V_m}{V_s}$ after subtracting out the wind error.

The results of the float discharges are set out in Table IX and Diagram 12. The relation between maximum surface velocity and mean velocity at Burifasas discharge site is shown in Diagram 11 and Table V.

TABLE IX.—DISCHARGES COMPUTED FROM FLOAT VELOCITIES STANDARDIZED BY CURRENT METER.
D_f=Discharge computed from float velocities=0·72×maximum surface velocity×area of section.
D_c=Current meter discharge.

DATE.		Burifasas Gauge.	Area of Section from Section-Gauge Curve.	Maximum Surface Velocity.	D_f.	D_c.	D_f—D_c.
1920		Metres.	Metres.	Metres per Second.	Cubic Metres per Second.	Cubic Metres per Second.	Per Cent.
August	20 ...	77·21	309·4	0·78	173·9	161·2	+ 8
„	21 ...	·24	312·6	·79	177·9	166·5	+ 7
„	24 ...	·31	319·6	·86	197·8	193·8	+ 2
„	26 ...	·36	324·2	·95	221·8	215·6	+ 3
„	27 ...	·37	325·7	·96	225·1	216·0	+ 4
„	28 ...	·39	327·8	·93	219·6	223·6	— 2
„	31 ...	·44	335·6	·98	236·9	244·4	— 3
September	3 ...	·46	339·0	1·06	258·7	244·8	+ 6
„	7 ...	·48	341·0	·07	262·6	267·5	— 2
„	16 ...	·52	346·9	·22	304·6	291·6	+ 4
„	18 ...	·56	351·6	·22	308·7	307·9	0
„	20 ...	·59	356·2	·25	320·6	326·1	— 2
„	21 ...	·60	357·6	·27	326·8	338·1	— 3
„	23 ...	·61	358·3	·31	337·9	333·7	+ 1
„	24 ...	·61	358·3	·32	340·4	337·1	+ 1
„	25 ...	·62	359·6	·27	328·7	339·3	— 3
„	27 ...	·61	358·3	·31	337·9	334·1	+ 1
„	28 ...	·61	358·3	·32	340·4	329·1	+ 3
„	29 ...	·61	358·3	·29	332·9	332·7	0
„	30 ...	·61	358·9	·38	356·7	337·2	+ 6
October	1 ...	·61	358·9	·28	330·9	336·4	— 2
„	2 ...	·63	361·6	·31	341·0	347·7	— 2
„	4 ...	·62	359·6	·34	347·0	342·6	+ 1
„	5 ...	·61	358·3	·32	340·4	336·2	+ 1
„	6 ...	·61	358·3	·30	335·4	333·5	+ 1
„	7 ...	·60	357·6	·23	316·8	333·3	— 5
„	12 ...	·60	356·9	·30	334·1	322·0	+ 4
„	16 ...	·59	355·6	·19	304·7	319·9	— 5
„	20 ...	·57	353·6	·23	313·3	309·2	+ 1
„	23 ...	·54	349·0	·13	284·1	294·3	— 3
November	5 ...	·45	337·0	·03	250·1	241·8	+ 3
„	17 ...	·36	324·2	0·93	217·2	202·2	+ 7
„	20 ...	·35	323·2	·87	202·3	193·3	+ 5
December	4 ...	·24	312·0	·63	141·6	154·4	— 8
„	14 ...	·20	307·9	·66	146·3	137·3	+ 7
„	23 ...	·14	301·8	·61	132·5	116·4	+14
1921							
January	3 ...	·07	294·6	·52	110·2	98·1	+12
						Mean ...	+ 2

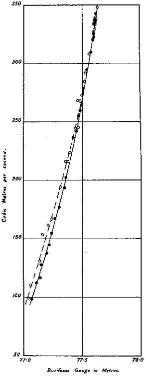
(iii) THE RELATION BETWEEN MEAN VELOCITY IN THE VERTICAL AND HALF-DEPTH VELOCITY AT BURIFASAS DISCHARGE SITE.

At the top of the flood a large number of observations of velocities at different depths were taken at each of 15 selected points across the discharge section. From these observations vertical velocity curves were constructed and the ratio—mean velocity: half-depth velocity—computed from them (*see* Diagrams 13*a* and 13*b*).

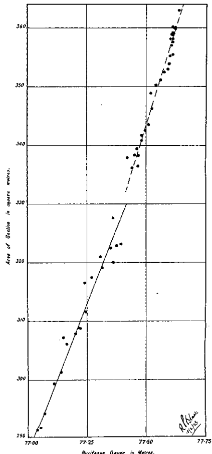
The mean value of this ratio was found to be 0·92 and its probable error 0·5 per cent.

Diagram Nº 10.

GAUGE DISCHARGE CURVE
BURIFASAS DISCHARGE SITE



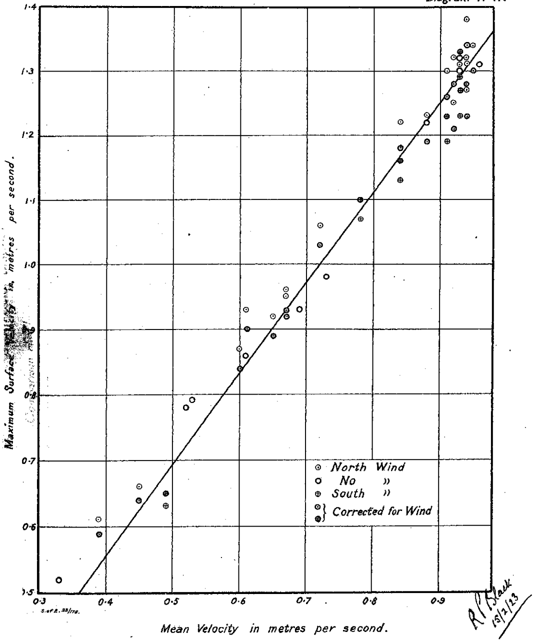
SECTIONAL AREA BURIFASAS DISCHARGE SITE



Datum . Burifasas Bench Mark (R. L. 79·701)

RELATION BETWEEN MAXIMUM SURFACE
VELOCITY AND MEAN VELOCITY
BURIFASAS DISCHARGE SITE.

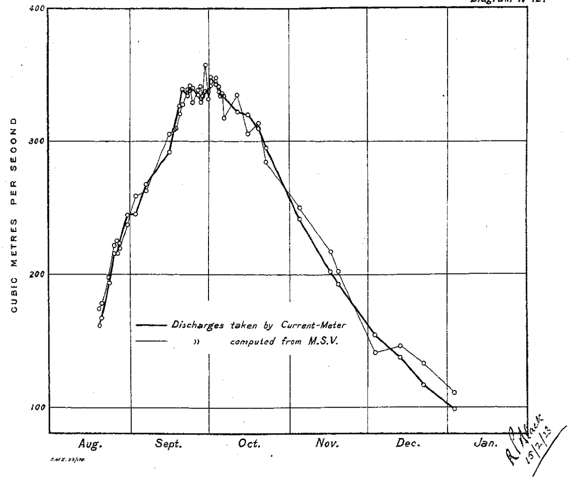
Diagram Nº 11.



BURIFASAS DISCHARGE SITE

Comparison of float and Current-Meter discharges.

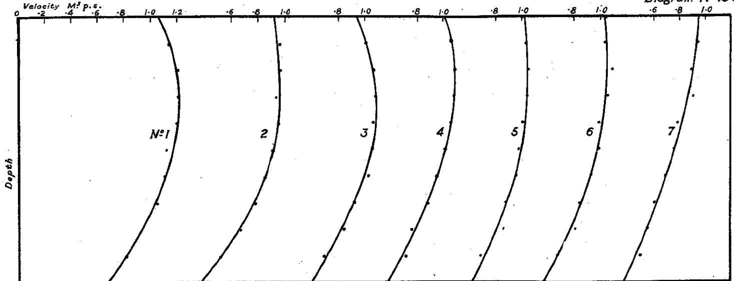
Diagram Nº12.



VERTICAL VELOCITY CURVES.

BURIFASAS DISCHARGE SITE OCT. 1920.

Diagram Nº 13a.



S. of E. 23/178.

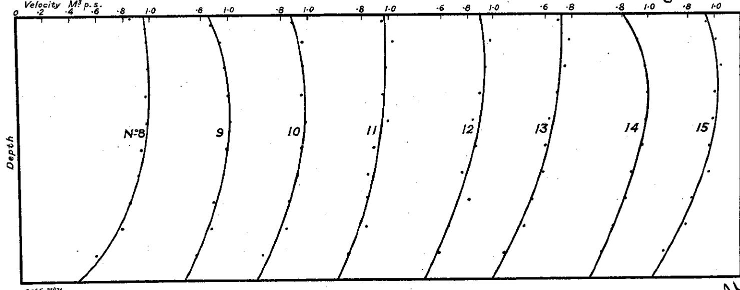
Nº	Depth m.	Mean Velocity / ½ depth velocity
1	2·40	0·92
2	1·70	0·89
3	2·32	0·90
4	3·45	0·93
5	4·28	0·94
6	4·81	0·94
7	4·04	0·95

R P Black
15/2/23

VERTICAL VELOCITY CURVES.

BURIFASAS DISCHARGE SITE OCT. 1920.

Diagram Nº 13 b.



Nº	Depth m.	Mean Velocity / ½ depth velocity
8	1·95	0·92
9	2·96	0·92
10	3·83	0·92
11	4·71	0·95
12	4·60	0·91
13	4·06	0·91
14	2·80	0·90
15	5·00	0·92

R P Black 15/2/23

CHAPTER VI.—BUILDING MATERIALS.

Stone.

It appears that any structures for the control of Lake Tana will be situated on the lava, the character of which has been described in Chapter IV. When these have to be built there will be no need to bring stone from great distances and quite probably all supplies required will be obtained either in making excavations for the foundations or for the channel through the cataracts. The crust of the lava forming the surface of the ground is generally spongy and vesicular and should be avoided, owing to its relative lightness, but the compact rock, to be found two or three metres below the surface or even on the floor of Chara Chara cataract, is an eminently suitable building stone for the regulator. It has a specific gravity of 2·67, a cubic foot weighing a little under 170 lbs. The fractured surface is rough and the stone should bind extremely well with mortar.

Good stone of the same type as the massive lava of the cataract exists on the surface of the lower slopes of the mainland, east and south-east of the northern end of Debra Mariam Island, where supplies might be easily quarried if the locality were found convenient. The slopes of the left bank of the river, especially at Tayima, Burifasas, and Egirrbar, offer excellent basaltic rock with specific gravities ranging up to 3·0, the cubic foot weighing over 180 lbs., but all these places seem likely to be inconveniently far away from the sites where building may be undertaken.

In a previous chapter it has been noted that the scoriaceous or spongy variety of the lava, abundant on the surface over most of the district on the west bank, are quite suitable and may even be preferable to the compact rock for building houses. It is lighter and probably does not conduct heat so readily.

Sand.

The paucity of sand in Abyssinia has been noted and no deposits of it were met with near the outlet. Mr. Herbert, however, has found a deposit of sand on the shore of the lake not far north of the outlet.

Extensive deposits of quite good basalt sand exist along the shores of the lake between the Fogara plains and the ruined church of Geraicha Arbatanza. These are referred to in the route report and in the description of that part of the country. The positions of other deposits of sand near the mouths of the Gumara and Reb rivers have been recorded by Mr. Buckley, who did not consider the quantities large. The region requires some exploration to find the most conveniently situated deposit, but there can be no doubt, especially with regard to the deposits on the shore north of the Fogara plains, that there is enough good sand to meet all requirements connected with works to control the water levels of the lake. They are situated along the shore and the sand could easily be transported to the outlet by means of barges.

The quartz sand of Delgi, mentioned in Chapter IV, is too fine grained to be desirable for use in mortar.

Limestone.

The only limestones met with were those belonging to the Antalo Limestones, at the Urgan pass and Ereisa Sardo on the south side of the Blue Nile at Kutai, and the older marbles associated with the metamorphic rocks near Abba Mendi. All these localities are too distant to be considered as sources of supply of limestone for works at the outlet of Lake Tana. No limestones were found among the bedded basalts and it appears most improbable that any can exist, consequently, the prospects of discovering limestone in the basaltic parts of the Abyssinian plateau are extremely remote.

The Antalo Limestone met with at Kutai presumably extends up along the valley, maintaining its position between the sandstones below and the basalts above. It occurs at about 2,000 metres above sea level, and assuming the bed is nearly horizontal, the Blue Nile may be expected to cross its outcrops perhaps in the Mota district not many miles below the First Bridge. This is the region nearest to the outlet of Lake Tana most likely to yield a supply of limestone and it deserves to be searched, provided it seems practicable to open quarries at a distance of perhaps 50 or 60 kilometres and organize transport. The alternative to this seems to be to import cement from Gallabat, where it must be brought either by camels or by motor.

Timber.

Supplies of good local timber are very limited and this can be gathered from the general aspect of the country shown in the photographs, especially 5, 14 and 29. The commonest trees are Acacia and Ficus and neither of these yield useful timber. The Abyssinians use timber in the construction of their churches, and these buildings are always surrounded by groves of trees, doubtless consecrated, to provide both shade for the holy ground and for repairs and upkeep. Around St. George's Church at Bahrdar the trees include Cordia, Am. *wanza*, and a few junipers, Am. *tid*. *Stille* is the name of another local wood. It and the wild olive, Am. *weira*, growing at about 2,500 metres, are both used in churches. The most important timber tree in Abyssinia is certainly the juniper, but this thrives best at altitudes of 2,500 to 3,500 metres and the trees near the church at Bahrdar Giorgis are rather poor examples. Juniper wood is often described as cedar.

In the process of surveying, a great deal of clearing was necessary; the finest trees were *Eugenia owariensis* Beauv., Am. *dogma*, but none were of sufficient stature to offer useful timber. The general conclusion is that there is no timber near the outlet suitable for beams, planks, and boards. It is possible that supplies of juniper for such purposes might be obtained from the Dankaz–Lebbo range, brought down to the north-east shore of the lake and thence by barge or raft to the outlet. Failing such supplies, requirements of that kind must be imported. The ordinary trees near the outlet may yield a fair supply of rough poles for use as supports and temporary scaffolding.

Ancient Structures.

Debra Mariam Church.

Here there are pieces of dressed stone, either a fine grained sandstone or more probably a volcanic tuff strongly resembling burnt brick in appearance. It is stated that a red stone was formerly obtained from quarries near Korata and was used in building the *Gimb* at Gondar. It seems likely that the Debra Mariam stone is from Korata and is of the nature of a tuff.

Bahrdar Giorgis Church.

The present structure is said to be about 250 years old, and though it is well built, with the usual grass roof, it does not present any points of special interest as regards material. Close by, however, is a three-storied tower used by the priests as the church storehouse. The upper rooms have vaulted roofs, there is a stairway outside and the whole is built with basalt stone and lime mortar. It no doubt belongs to the time when the influence of the Portuguese Jesuits prevailed and may have been built either by one of their craftsmen or by an apprentice. To-day, the people are unable to make a similar building and they know almost nothing about the former craftsmen.

The First Blue Nile Bridge.

This is sometimes known as the Agam Dildi or Alata Bridge and is described later in dealing with the route from Bahrdar Giorgis to Dembetcha. The bridge is built with lime mortar and the ashlar of the arches has been cut from some soft, partly weathered variety of basalt, said by the people to exist locally. The principal arch has a span of eight metres. Another bridge situated in the Mota district was not visited. Its main arch had a span of about 18 metres and was for many years broken, until repaired by some Italian workmen in about 1910. The feat of constructing, centring and erecting such an arch in all the circumstances, is one for which the Portuguese craftsmen of those days have our highest admiration.

The extensive buildings at Gondar, said to be partly built with stone from Korata, the various masonry bridges, the positions of some of which are shown on Map II, and also several churches in the neighbourhood of Lake Tana, are all attributed to the period of Portuguese influence. Though the materials of construction are often not mentioned by travellers, it is known that lime mortar was used in the more important structures and it was no doubt used in the others as well. The quantities required for some of them, such as bridges and churches, were relatively small and difficulties of transport may hardly have entered into consideration. Even with more extensive buildings such as those of Gondar, if much of the stone was actually brought from Korata, it is possible that the lime may also have been brought from a considerable distance. No reference has been found to the quarries whence this lime may have been brought, but the presumption is that it came from the Antalo Limestone beds lying beneath the bedded basalts and exposed on the slopes of the Blue Nile valley and perhaps also in the basin of the Takkazye east of Gondar. We do not yet know how far up the Blue Nile valley the outcrops of limestone may be traced, but in any case it seems clear that some of the lime used must have been carried great distances.

CHAPTER VII.—LAKE TANA AS A RESERVOIR.

General Considerations.

ROUTINE STORAGE.

Mr. Dupuis [1] pointed out that the conversion of Lake Tana into a reservoir should be carried out so as to disturb the existing conditions as little as possible. He suggested that it might be designed for a capacity of 3,000 millions of cubic metres with its full supply level at normal flood level. He assumed that the contents might be drawn off during 100 days preceding the beginning of the normal rise of the lake and pointed out that the effect of such regulation would be that, starting with the reservoir full as at present on October 1, its level would fall, under the influence of evaporation alone, more slowly than at present, until the draw-off began. The fall would then become more rapid and the lake would eventually fall some 32 centimetres below the present low stage level. He remarked that the whole effect of regulation would only be to increase the range of levels in the lake by 32 centimetres, giving slightly higher levels from October to March and rather lower ones from April to September. The recent investigations all tend to bear out these remarks and the suggestions below are actually only modifications of those put forward by Mr. Dupuis nearly twenty years ago. Even the present ones are only to be regarded tentatively, to be modified as information increases.

As Mr. Dupuis remarks, the crucial point in estimating the value of the lake as a reservoir is the amount of its discharge, for this is the volume that can be controlled. On the basis of the observations detailed in Chapter V, it appears that the flood of 1920 can be regarded as an average one. If this proves to be correct a volume of about 3,500 millions of cubic metres may be controlled in such years.

RESERVE STORAGE.

The possibility of storing water at Lake Tana from year to year as a reserve to meet the requirements of very low years was recognized by Sir Murdoch MacDonald.[2] The capacity required depends essentially on the volume available from the lake in average years, since this governs the quantity of cultivation to be safeguarded. The limits of lake levels are of first importance in determining what amount of reserve is required and how it is to be built up. Computations show that the level of the lake in a low year is of secondary importance to the amount of water that can be taken from the river without interfering with its flow during the low stage. In a very high year, however, the order of importance is reversed and consequently it is very necessary to obtain records of the lake levels during high floods.

In a year of high flood the volume stored in Lake Tana until December 31 may be 4,500 millions of cubic metres and probably the greater part of this can be placed in reserve. In such a year, not only will more water fall into the lake but the ordinary routine requirements of the cultivators may be met to a large extent from the natural flow of the river.

(1) "Basin of the Upper Nile," *ibid.*, p. 225.

(2) "Nile Control," Cairo, 1921, p. 123.

Thus, the carry-over from a high year would be more than enough to tide over the deficiency of a low year and it seems quite feasible to form a reserve of 8,000 millions of cubic metres. It must be borne in mind that these estimates of the reserve storage required and available in high and low years are based on assumed levels of the flood level of the lake in such years. Further information is required, but meanwhile the figures are of interest as an approximation based on data now available.

Capacities of the Reservoir.

As a result of Mr. Buckley's surveys of the shore, it is known that the area of the water surface increases by about 4 per cent between 79·00 and 81·00, or at the rate of 1 per cent for each 50 centimetres rise of the water level. On page 11 it has been shown that the lake has an area of approximately 3,000 square kilometres and assuming that this is true with water level at 80·00 the following reservoir capacities have been estimated :—

Table X.—Estimated Capacities of the Lake Tana Reservoir.

Levels.	Capacities.	Accumulated Capacities.
Metres.	Millions of Cubic Metres.	Millions of Cubic Metres.
80·00–81·00	3,030	3,030
79·00–80·00	2,970	6,000
78·00–79·00	2,910	8,910
77·00–78·00	2,850	11,760
76·00–77·00	2,790	14,550

It is seen that if the lake is controlled through levels ranging from 81·00 to 76·00 a total capacity of 14,550 millions of cubic metres is involved, but, as is shown below, the effective capacity may only be about 11,800 millions of cubic metres.

Losses.

So long as the range of water levels remains approximately the same as at present, losses due to evaporation and seepage will continue at almost identical rates. If the works are arranged so that the maximum level of the reservoir is at 81·00 and the regulator remains closed until January, the water level will then be about 50 centimetres above the natural level of the lake at that time and the evaporating surface will be correspondingly greater. When the normal routine storage volume is completely discharged towards the end of April, the water will stand 50 centimetres below the natural lake level for that time and evaporation losses will be correspondingly less. The foregoing line of argument is only slightly affected by the time of emptying. If the water is drawn off early, the reservoir area will exceed the natural lake area for a shorter time than if the process is delayed. On such grounds it can be assumed that the reservoir will not cause any extra losses, even when it is operated for routine storage only, through the highest part of its range. When reserve storage is drawn on and the water stands at lower levels, the losses will be correspondingly diminished.

It has already been remarked that the reservoir capacities given in the table above are not completely effective. Approximately 140 centimetres depth of water is annually lost by evaporation from the surface of the lake, but part of this occurs while the lake is filling and its effect on levels to that extent is annulled. The rest of the loss, corresponding to about 90 centimetres depth of water, must be allowed for in estimating the effective capacity of the reservoir for any set of levels. For instance, if levels are controlled in a normal year from 81·00 to 79·00, corresponding to a total volume of 6,000 millions of cubic metres, about 90 centimetres depth of water will be lost and the effective capacity will be about 3,300 millions. A similar allowance must be made in estimating the effective capacity of the reservoir for any other range of levels. In order to provide for 3,500 millions of cubic metres of routine storage as well as a reserve of 8,000 millions of cubic metres, water levels will have to be controlled from 81·00 down to 76·00 metres.

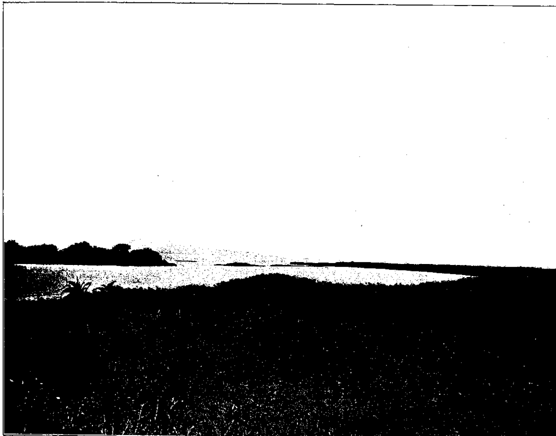
Design of the Works.

RANGE OF CONTROL.

The highest natural flood level of the lake has been determined as approximately 81·30 metres and it seems essential that the water, even under exceptional conditions, should never be held up above this level. Provided the Abyssinian Government agrees to the sill being lowered, a very positive guarantee might without detriment be given that such a level will never be exceeded. The following suggestions are, however, based on a maximum reservoir level of 81·00 and this has been adopted because it is considered that the works required to hold the water up to this level are simpler than would be the case if water was to be held up to 81·30. The country at the outlet is low and any reservoir level above 81·00 involves the necessity of considerably longer *sadds* to close the subsidiary overflow. The neighbourhood of the outlet is described in Chapter IV with special reference to the construction of control works.

With the object of regulating the waters of Lake Tana in the best interests of the cultivators in Egypt and the Sudan, it is suggested that the works at the outlet should, at first, permit control through a range of three metres below 81·00. Such a range after allowing for evaporation, which as Mr. Dupuis noted is the most important factor in controlling the level of the lake under natural conditions, provides a reservoir of 6,200 millions of cubic metres capacity. This is nearly twice as much as can be filled in ordinary years, when an average of about 3,500 millions of cubic metres is available, and the excess is intended for the accumulation of a reserve to be carried over from years of plenty to help to safeguard the cultivation in years of low supply. The suggested maximum level of 81,00 and a range of 3 metres of control involve the reservoir being emptied down to 78·00, or approximately 1·50 metres below the present low stage level of the lake.

Though we feel confident that existing data are enough to justify control of water levels through a range of three metres, we recognize that there may be reasons, and among them political considerations, such as may not at the outset permit the carrying out of permanent works giving that range. Any provisional scheme would doubtless be arranged so that it might be expanded, and suggestions on these lines are given later on.



No. 24.—North Debra Mariam Outlet.

THE REGULATOR.

To enable the suggested range of control to be achieved, a masonry regulator such as Mr. Buckley has proposed may be built towards the west end of the outlet at the south end of Debra Mariam Island. For the present purposes it is only necessary to assume some sort of structure to show that the reservoir may be controlled as desired, and we are indebted to Mr. Buckley for having allowed us to refer to his suggestion. The work he has outlined has fourteen openings, each 5 metres wide with piers 2 metres thick and sills at 74·00 metres and bears some resemblance to the type of structure at the headworks of many of the larger canals in Egypt. At Lake Tana fourteen openings are expected to have to pass a discharge of 350 cubic metres a second and it seems desirable that this should be maintained down to 78·00 metres, the lowest reservoir level. The sills being placed at 74·00 provides waterway at the regulator and allows for future expansion. The lower limit of the range of control will be determined by the levels of the approach from the open lake. The regulator may have to stand a head of 8 metres when the reservoir is full and the channel downstream is empty, but there is a foundation of solid rock, while in Egypt such headworks stand on sand or clay. In order to permit of the construction of such a regulator an earth *sadd* will have to be placed upstream of it. Presumably this will be placed as far up towards the lake as possible and the regulator will be built immediately downstream in approximately the position shown in Map III and Photographs 1 and 2. The latter is taken from trigonometrical station "X" on Shimmabo Island, looking down the South Debra Mariam channel, and the proposed site for the regulator lies between two points and crosses the water on the nearer side of the *tankwa*. It seems desirable that the structure should be as far up the channel as possible. Apart from the apparent convenience of this site for the regulator, Mr. Herbert's soundings have shown that it provides the best line of approach from the deeper water of the lake.

THE *Sadds*.

Besides the channel where it is suggested that the regulator should be placed, there are two other outlets which have to be closed before control can be assured. It is suggested that this should be done by means of *sadds* of earth and rock. One of these may take advantage of a line of rocky islands across the channel, about 400 metres wide, at the north end of Debra Mariam Island, shown in Photograph 24. As noted in Chapter IV, the northern end of the *sadd* would have to curve eastwards, crossing a stretch of low ground underlain by basalt, to tie on to the slopes of the mainland. Another will be required to close the outlet through the Ifwadda Lagoon, illustrated in Photograph 25. The most favourable place appears to be between two rocky points requiring a bank about 180 metres in length in the position shown on the plan. This locality offers the advantage of cutting off several large swamps where mosquitoes breed freely and the district will certainly be more healthy as a result. The Ifwadda outlet might be closed by a shorter and smaller *sadd* across the channels leading from it to the cataracts. This, however, would be below the swamps, which would be flooded longer and make the place more unhealthy. A better alternative is offered by Hanna and Arsema Islands, which might be connected together

with *sadds* and to Shimmabo Island as well as to the mainland to close the mouth of the lagoon. While these could be arranged to cut off nearly all the existing swamps, the scheme is open to the objection that some of the *sadds* might be exposed to the full force of waves from the open lake and they would have to be correspondingly strongly made. At present we have no soundings between these islands to indicate the depths of the channels that would have to be closed. A small bank will be required along a low part towards the north end of Debra Mariam Island where there is a spill during the higher stages of the flood. The floor at the places where it is suggested that these *sadds* should be placed is at relatively high levels and they will not have to withstand heads of more than about 3 metres. It may be considered that these *sadds* should be strengthened with thin core walls.

Excavated Channel Downstream of the Regulator.

The level of the lake is naturally maintained by a basalt ridge generally referred to as the Upper Reef already described on page 47. The water level falls about 1·5 metres across this barrier and in order to empty the reservoir to 78·00 metres a channel must be excavated through it and for some distance downstream, in much the same way as Mr. Dupuis proposed. This should be designed to carry the full discharge that has to be withdrawn, from the lowest levels of the reservoir. The excavation will be mainly in rock and consequently a design with vertical sides and a width of ten metres seems economical. With a reservoir level of 78·00, the level downstream of the regulator for a discharge of 350 cubic metres a second is found from the formula :—

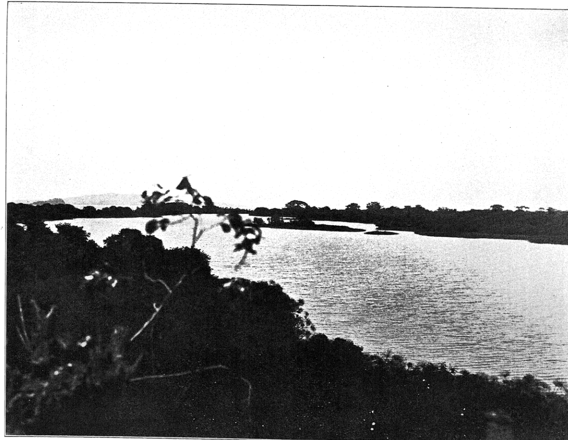
$$Q = CL\sqrt{2gd_1}\,[d_2 + \tfrac{2}{3}\,d_1]$$

where d_1 = difference of water level upstream and downstream, and d_2 = the head of water above the sill downstream. In this case :—

$$C = 0{\cdot}82$$
$$L = 70$$
$$d_1 + d_2 = 4$$
$$Q = 350$$
$$\text{Whence } d_1 = 0{\cdot}12$$

Thus the difference of water level upstream and downstream of the regulator is 12 centimetres.

This involves a velocity of 1·25 metres a second through the sluices and the water-level downstream of the sluices will be 77·88. The best line for the excavation of the channel appears to be that shown on Map III, traversing the Egirrbar Hills by means of a tunnel. If this is adopted, the excavation from the regulator to the entrance of the tunnel will be 8 kilometres long, and is estimated at 768,500 cubic metres. The tunnel will be 550 metres long, involving 60,500 cubic metres of excavation. Such a design of the channel permits a slope of 110 centimetres in the kilometre and with a width of 10 metres and depth of 10 metres it will pass 350 cubic metres a second. The cross section of the tunnel may be almost the same as that of the channel, but the top will presumably be arched and will rise to above the water surface to allow an air space. These works are shown diagramatically on Diagram 14. The water level at the outlet of such a tunnel on the



No. 25.—The Ifwadda Lagoon Outlet.

south side of the Egirrbar Hills will be 68·50, while the natural water level of the river when carrying 350 cubic metres a second is below 66·00. The actual water level in the river, corresponding to that discharge, at a point about 600 metres upstream of the probable position of the outlet of the tunnel, is 65·97. The upper part of the tunnel may therefore discharge freely into the air, while a sloping floor, excavated in front of the outlet, may connect the lower part of the tunnel with the natural bed of the river. The floor of the tunnel at the outlet is shown at 58·50 or considerably below the ordinary low stage water level. To enable this to be excavated without the use of pumps and also to facilitate the removal of debris subsequently, it is suggested that a drain 2 metres wide with the bottom at 58·50 may be cut to the Arafami falls 1,600 metres below the outlet. Here Mr. Herbert has found a fall of nearly 7 metres at low stage, but the level of the river below the falls is still unknown, consequently the slope of the drain cannot be specified. Such a work, however, involves about 20,000 cubic metres of excavation in rock. The excavation suggested may be tabulated as follows :—

	Cubic Metres.
Channel between Regulator and Tunnel	768,500
Tunnel	60,500
Channel at outlet of Tunnel	6,000
Drain	20,000
TOTAL	855,000

Unfortunately some surveying is still required to complete the mapping and contouring of the river bed downstream of Kamforo to which it was practically finished early in the spring of 1921. Consequently parts of the present longitudinal section, shown by the broken lines, are subject to modification. The data is, however, complete enough to enable it to be stated that the estimated cube of excavation will not be increased. The excavation will be mainly in solid basalt and this will require blasting. The river bed may prove to contain hollows filled with alluvial deposits and as soon as the channel downstream is opened the flow of water will remove the loose materials. In estimating the cubes, no account has been taken of places where the width and depth of the natural river bed is great enough to permit a reduction in the size of the excavated channel. The figure will certainly be reduced when this is done. However, for the present it seems safer to base estimates on the assumption that the whole excavation will be in solid rock. As already remarked, a channel with vertical sides seems likely to be both economical and convenient, and with the relatively high slope of 110 centimetres in the kilometre, it will cause the water to flow with a mean velocity of about 3·5 metres a second. This, however, is permissible on account of the solid rock in which it has to be excavated. The velocity of the water along the slope may be of considerable assistance in the later stage of excavation, as it may be possible to wash out the loosened debris by flushes of water instead of laboriously carrying it out.

The alternative to making the tunnel, is to align the channel down the narrow western branch of the river at Burifasas and follow the bed of the river through the discharge site at Egirrbar and beyond to the Faras Egr falls. The excavation of the main channel would end at Jirmidi, where the natural water level for a discharge of 350 cubic metres a second is 65·97. This line would be 10·5 kilometres long and the drain downstream to Arafami would be 1·7 kilometres long or only slightly longer than that required downstream of the tunnel. The adoption of the 550 metres length of tunnel therefore offers a saving of 2 kilometres in the cutting or approximately 170,000 cubic metres of excavation.

It avoids the long bend round the Egirrbar Hills, permits a slightly greater water slope and gives a much better alignment. Around the Egirrbar bend the excavation is certain to be entirely in rock, while on the line immediately upstream of the tunnel there may be deposits of silt. The tunnel line is far more favourable for expansion when it is desired to increase the range of the reservoir down to 76·00. It will enable full advantage to be taken of the drop at Arafami falls, if this is ever required.

THE APPROACH FROM THE LAKE TO THE REGULATOR.

Some excavation upstream of the regulator will be necessary and the matter is dealt with later.

Method of Carrying out the Works.

FIRST SEASON.

The amount of masonry construction involved in the regulator is very small and the main problem will be the transport of materials that have to be imported. For the rest, the *sadds* are matters of rock and earthwork, while channels have to be excavated in either rock or silt.

When diplomatic negotiations culminate in permission to convert the lake into a reservoir and operations can be commenced, the urgent need of additional supplies of water in Egypt and the Sudan will certainly render it desirable to proceed with the works at the outlet with the least possible delay. Even if it is decided eventually to make a railway or a motor road, a rough track should be cleared forthwith and porters and mule transport organized to bring materials up the escarpment to a convenient point on the lake shore, perhaps near Delgi, where a depot may be established. Among the first items to be transported will be several steel sailing boats or barges and perhaps a small launch or tug, all in sections. These will be required for communication, which must be established across the lake as soon as possible. Craft on the lake are also necessary for bringing sand from the eastern shore. The amount of mule transport is limited and this should be concentrated on the road up the escarpment leading to the lake. It will be highly uneconomical for mules to proceed on the road to Bahrdar Giorgis beyond the depot on the lake shore. On the Sudan side, the farther camels or light cars can be worked along a roughly cleared track beyond Gallabat towards the foot of the escarpment, the less will be the length of carry required from mules or porters and the greater will be the efficiency. The carriage of long materials such as timber and ironwork will be limited to what can be handled by porters until mechanical means are available for ascending the steep part of the route. If suitably designed, the regulating works at the outlet of the lake may be constructed without establishing permanent means of communication such as a railway or a motor road. The reservoir might, in fact, be complete and working before a railway or motor road reaches the lake, and temporary gates, etc., in the regulator might be replaced subsequently by more permanent ones.

It will be advantageous if the parties of engineers and skilled workmen are in readiness to start work immediately after the rains. The earliest date for departure from Khartoum can be assumed to be November 1 and Abyssinia can be entered at Gallabat on about November 20. The first matter to engage attention at the outlet is the erection of



No. 26.—From Top of Tree showing Cataracts across Upper Reef.



No. 27.—Rocks at Head of Chara Chara from West Bank.

accommodation for the engineers and workmen. Some permanent houses will be required and these can be built as cement arrives in the course of the dry season. They may be situated either on Debra Mariam Island or Shimmabo Island. If it is decided to make the tunnel at Egirrbar a labour colony near its outlet may be convenient, others may be arranged near the line of the channel and a good road will be an advantage. A few tents will be required, but it will involve less transport and prove more comfortable if the men are housed for the most part in thatched huts. The grass should be collected early, as it is liable to be burnt off on becoming dry in March. Apart from a few houses, no constructional works are likely to be undertaken during the first season. Materials for use during the second season can therefore be accumulated. It will probably not be wise to store cement during the rains in Abyssinia unless special precautions can be taken to prevent deterioration. If these can be arranged and cement can be transported and stored in readiness, it will be all to the good. Sand can be brought from a selected spot on the lake shore.

As soon as labour, explosives, and tools are available, work may be begun on the tunnel, starting at its outlet. The first heading will be comparatively small and possibly three shifts of workmen will be employed, so that the hill may be pierced as soon as possible. The heading would be along the crown of the tunnel and deepening and widening can proceed later. Towards the end of March, the river will have fallen enough to permit work on the cataracts and channel to be undertaken. This will be carried out with the object of lowering the sill at Chara Chara so that the lake during the following flood may discharge more freely, and low levels will be attained earlier in the succeeding season to facilitate the making of the *sadds* and other constructional works. Towards the end of May the discharge from the lake will have fallen so low that work will be possible on the channel downstream of the cataracts. This may be facilitated by placing small *sadds* across the cataracts that are still discharging. Work on the drain along the line of the channel between the regulator and the tunnel can then begin. The object of this will be to enable the water to drain away from the downstream side of the *sadds* at the outlets and regulator site. It will probably be only 2 metres wide where it has to be excavated in rock but it will render the use of pumps unnecessary for the purpose of unwatering.

At this stage, when the bed of the river is almost dry, it may be possible to start work at the upstream end of the tunnel and drive a heading to meet the other coming from the south. To facilitate this, either a small amount of work may be done on the floor of the river to allow standing water to drain away to the west or a *sadd* may be placed around the site of the inlet. There is unlikely to be any serious trouble with water after the river bed has been drained, but three or four small hand pumps should be provided. The completion of the tunnel, even in a preliminary small way, will allow the floor of the drain to be excavated to the required depth for the regulator site to be unwatered down to 73·00 m. level. If the drain is not completed during the first season, it can be completed as soon as the outlets are closed by *sadds* in the second season. If the tunnel is not pierced during the first season, work on it can continue during the rains to a stage that will allow it to be holed through immediately conditions are suitable. If it is pierced during the first season, the entrance will be submerged during the flood and the interior will not be approachable until the discharge is stemmed by the *sadds* at the outlet of the lake. There will probably be no objection to this, as labour is likely to be scarce during the period of the flood. The rainy season will begin while the lake levels are still favourable for work

and a little trouble may be caused by spates from the Chimbil. By the time the lake rises and spills over the temporary *sadds* on the cataracts the rainy season will be so far advanced that it will be impossible for the staff occupied at the lake to return to the Sudan unless wonderful progress has been made with the road. As regards animal transport and cars travelling over the unprepared surface of the soil, the road from Gallabat to Delgi can be regarded as becoming unusable at the end of May. Transport and any work on the road must stop at that time and the engineers will be withdrawn from that part to more healthy regions.

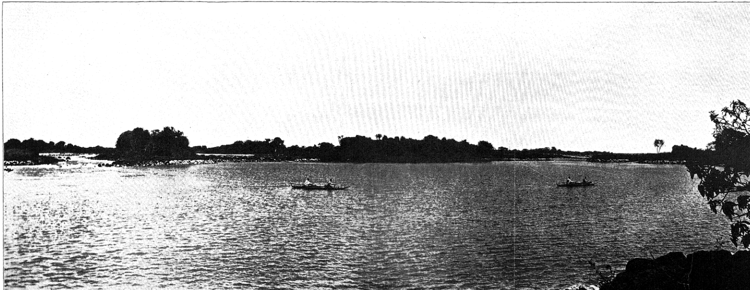
The weather at the lake during the rains is almost always fine from dawn until midday and it will be possible to assemble steamers and barges not already put together. Any road making at the outlet can be completed with a small party of men, but the Abyssinian labour, for the most part, should be paid off to return to their homes to cultivate during the rains and afterwards to return with fresh recruits.

Second Season.

The work of the second season will probably begin as soon as it is possible to close all the outlets with *sadds*. Two of these are likely to be made permanent and the third will be temporary, to close the channel just upstream of the regulator site. If the lake levels are favourable, all *sadds* may be completed before the end of December. Immediately this is achieved, the tunnel can be pierced if not already done, and the drain can be completed through the upper part of the cataracts to enable the regulator site to be unwatered down to foundation level. Construction of the regulator will proceed and as much labour as is available can be applied to the excavation of the channel downstream. The regulator should be complete before the end of the dry season and ready to withstand the water pressure as soon as the lake rises over the temporary *sadd*. The presence of the regulator and the permanent *sadds* will keep the channel downstream free of water from the lake, and if the excavation is not completed, it may continue until the time comes to inaugurate the reservoir by opening the regulator and sending down its contents to supplement the Nile's supply for cultivators in Egypt and the Sudan.

When the regulator is actually holding up the water it will be possible to open the gates and send down flushes as occasion requires, to remove debris that have been broken by blasting in the channel. This may be a very material help, especially at the tunnel, where it might save the debris from having to be handled and carried out.

It does not seem necessary to undertake the excavation of the approach from the lake until after the regulator is functioning. Conditions for the work will be far more suitable when the reservoir has been emptied as far as natural levels of the lake floor permit. Even though the level of the approach is high, the width of the water section will allow a considerable discharge to be maintained until quite shallow depths are attained. The material will be either rock or clay and most probably rock covered with clay. It is suggested that the work will be readily done with the aid of some form of sheet piling, or by caissons, permitting areas to be unwatered. There is no question of excavating deeply, but the section must permit free water passage to the regulator. If this part of the work is delayed until after the regulator is complete, it may not be possible at first to draw on the reserve storage to the full extent. The routine storage, however, will all be available.



No. 28.—Cataracts across Upper Reef from Downstream.

Provisional Measures.

The foregoing proposals relate to control through a range of three metres, but if it is felt that provisional works are desirable at first, these may be designed so as to fall into line with, and contribute to, the larger scheme. In any case, before the permanent regulator can be built, the channel must be closed by means of a *sadd*. This might be provided with temporary sections, which could be cut when it is desired to let out water and reformed when the outlet has to be closed, or part of it might be a lightly built and quite provisional masonry structure. The preliminary works might aim at allowing the reservoir to be drawn off to about 78·50 to give enough storage, so that the normal flood level 81·00 m. may not be exceeded even by a high flood. A certain amount of excavation would have to be done along the line of the channel, especially the part through the Upper Reef. The efficiency of control would depend partly on the channel, which might limit the rate of discharge, unless it is made to carry the full discharge at the lowest levels of control. To achieve this, full waterway must be provided in the channel through the cataracts, and in fact the excavation would be only about 50 centimetres shallower than the depth required for the three metres of control. Even if the full discharge of 350 cubic metres a second were only to be maintained down to the 79·00 m. level of the reservoir, the amount of excavation in the channel would only be reduced by about one-tenth and the usefulness of the reservoir would be reduced out of all proportion to the corresponding small difference in cost. The method of procedure in excavating the rather shallower channel should be similar to that outlined for the full-sized channel, a small tunnel through the hill at Egirrbar and a drain along the line of the channel being among the first items to be undertaken, so as to provide for unwatering in the neighbourhood of the head works. It may be emphasized that a certain amount of excavation must be undertaken along the line of the channel in order to be able to guarantee that a level such as 81·30 should not be exceeded. In the provisional scheme, the other outlets must still be closed by *sadds*, and in fact the saving in cost relates principally to the permanent regulator, and this would be partly counterbalanced by some extra expense in constructing the *sadd* in the South Debra Mariam channel so that it might be opened and closed. The requirements for imported materials would be reduced, but the cost of clearing the track to the lake and communication across the water would remain the same as for the permanent scheme. It appears that a period extending through two low-stage seasons would be required for the construction of the temporary works, consequently they do not offer the advantage of an earlier date of control as compared with the permanent scheme. The suggestions for provisional works have been limited here to such as may be regarded as falling into line with permanent methods of control. Some alternatives for preliminary measures are referred to later on p. 94, but we state now that neither those already outlined nor the alternatives are commended as opposed to permanent works giving an initial range of 3 metres of control and allowing for expansion. The limited results of smaller ranges of control are referred to on page 100.

Future Expansion.

The suggested permanent regulator with its sill at 74·00 m. would allow the reservoir to be developed by further excavation of the channels. When requirements demand

control over a greater range, the channels can be deepened to allow the reservoir to be emptied to 77·00 and finally to 76·00 m. This will increase the capacity for reserve storage to about 8,000 millions of cubic metres which will probably be as great as can be of practical use. The increase in the capacity of the reserve storage does not increase the average amount of water available from Lake Tana, but it enables it to be distributed to greater advantage.

It must be understood that all the foregoing suggestions are only put forward in the most tentative manner. Much more information is yet required and no attempt has been made to forecast the actual design of the regulator, *sadds* and channel.

Estimates of Cost.

Cost of the Regulating Works.

The cost of works to control the lake water levels through a range of three metres from 81·00 to 78·00 and designed to permit of some further expansion can only be accurately estimated when the conditions under which they have to be carried out are known. In our forecast it has been assumed that they will be designed, avoiding the use of large timber and heavy ironwork in the regulator, so that all essentials may be brought to the lake by means of porters, mules, camels and motor cars, without the need of establishing a permanent means of communication. It may, however, be regarded as essential to be able to reach the lake by mechanical transport principally for the purpose of keeping in touch with the staff in charge of the reservoir when this is functioning. As it appears that neither a railway nor a motor road leading to the lake is essential to the construction of regulating works at the outlet, they may be relegated to the future and will be dealt with later.

The regulator and *sadds* have been estimated to cost about L.E. 600,000. This depends largely on the cost of obtaining cement, as there is no lime available near Lake Tana. All the timber and ironwork must be transported. Stone is obtainable locally and sand can be brought in boats from the shores of the lake. There is plenty of earth available for making *sadds*. It is assumed that a considerable amount of unskilled albour will be obtainable locally at relatively low cost. As regards the cost of excavation of the channel and tunnel downstream of the regulator, it has been ascertained that excavation in hard rock at Makwar, including cost of explosives, tools, and cost of stacking, has been done for about P.T. 30 a cubic metre. In view of the remoteness of Lake Tana a considerable margin must be allowed and it does not seem safe to adopt a figure of less than P.T. 100 a cubic metre. At this rate the cost of the channel, tunnel and drain will be L.E. 855,000. The excavation in the tunnel, until the hill is pierced, will cost more, and it is probably safer to adopt L.E. 1,000,000 as the cost of these works. Mr. O. L. Prowde, Resident Engineer for the Gezîra Irrigation Scheme, very kindly gave us some most instructive notes about the cost of excavation in solid rock connected with the Makwar dam.

A sum of L.E. 200,000 may be allowed for the cost of excavating the approach channel from the open lake to the regulator.

The rough estimates may be briefly stated as follows:—

	L.E.
Regulator and *Sadds*	600,000
Channel and Tunnel downstream of Regulator	1,000,000
Excavation upstream of Regulator	200,000
Housing	200,000
Road clearing	100,000
Barges and Steamers on Lake Tana	200,000
	2,300,000

These figures contain allowances for transport from Gallabat on imported materials to cover cost of motor cars, mule and camel hire. Road clearance will be required in any case and is covered by a special item, and craft for communication across the lake are covered by another item. It is obvious that any basis these figures possess is very uncertain and at the best they are to be regarded as being submitted quite tentatively.

Cost of Permanent Means of Communication.

If mechanical means of reaching Lake Tana are required, the alternatives seem to be a motor road with light lorries, a full-sized or a light railway, and it is assumed in any case that the main line of the Sudan Government Railways will exist at Gedaref. Whichever of these is adopted, it will have to surmount the steep slopes of the edge of the Abyssinian plateau. The level of the lake is about 1,000 metres above that of Gallabat and higher ground on the edge of the escarpment must be crossed before the lake can be reached. The distance from Gedaref to Gallabat is 153 kilometres, from Gallabat to Delgi it is 140 kilometres, and margins must be allowed for turns and detours, so that the distance along the route from Gedaref to the lake can hardly be less than 320 kilometres. The difficulties were explained briefly to Major P. Lord, R.E., Chief Engineer of the Sudan Government Railways, and he suggested that an extension of the Sudan Government Railways to Delgi might be constructed for about L.E. 2,500,000, provided a route could be found that did not involve tunnelling. There can be no doubt that such a railway, apart from maintaining communication with the reservoir, would be most valuable in promoting trade relations between Abyssinia and the Sudan. A light railway might be cheaper, but its disadvantages would probably not compensate for the smaller cost.

The motor road appears to be the alternative to the full-sized railway. Steeper gradients can be negotiated and a route could be more easily engineered up the slopes. Many streams would have to be bridged and there would be about 200 kilometres across the *badob* soil of the Sudan plains. This cracks badly when it dries after the rains, and though it withstands light traffic during the dry season, heavy traffic would soon cut it up badly. If the road is to be of use during the rains it will have to be metalled, and this will be costly. Cuttings will have to be made on the faces of some of the steep slopes of the Abyssinian escarpment. It is clear that a motor road will not be easily or cheaply constructed and it will not be of much value for trade. Probably it would not be safe to adopt any figure below L.E. 1,000,000 for the cost of construction of a properly metalled road usable at all seasons from Gedaref to Lake Tana. The motor road offers the advantage that it can be constructed and made available for traffic far more quickly than either the full-sized railway or the light railway. The few experiments with tractors in the Sudan,

hitherto, have given poor results. The consumption of petrol has proved very heavy, especially as the great heat of the climate promotes large losses, even from unopened drums. However, modern developments seem likely to reduce petrol consumption, or perhaps these difficulties may be avoided by adopting machines using other kinds of fuel.

It is seen, therefore, that if a motor road or a railway has to be constructed, L.E. 1,000,000 or L.E. 2,500,000, as the case may be, must be added to the estimated cost of constructing regulating works at the outlet of the lake.

Alternative Suggestions.

Regulating Works at Points Lower Down the River.

One of the earliest proposals was to place the regulator at Egirrbar about 9 kilometres below the outlet. The objections to this appear to be that the regulator would have to be of considerable length and height to establish the requisite control. Where all the cement or lime will have to be brought at great expense from considerable distances there appears to be much in favour of the sites where the minimum amount of masonry is necessary. The excavation of the channel through the cataracts upstream of the regulator would be more difficult owing to the water being held up to some height above it during a great part of the year. These objections also relate to sites nearer the lake right up to Chara Chara, which has also been proposed as the site of a regulator. This place is at the cataract across the Upper Reef, which is where the deepest cutting will be required in order to be able to draw off the reservoir below the present lake levels. If a regulator were to be placed here, additional excavation would be required to provide space for it. The other cataracts would have to be closed by *sadds* and the works would only permit of a relatively small amount of regulation, which it would be impossible to increase without costly excavation along the line of the channel connecting the regulator with the deeper part of the lake outside the South Debra Mariam outlet. Another objection to placing the regulator at Chara Chara is that the very extensive mosquito-breeding swamps existing alongside the Debra Mariam Lagoon would remain and would continue to make the region too unhealthy for the residence of the controlling staff. The extent of these swamps is shown in Map IV.

Alternative Provisional Works.

If a provisional work were made at Chara Chara it appears that besides being relatively costly to begin with, owing to the amount of additional excavation necessary to provide room for it, it would have to be abandoned later when the range of control has to be increased and a permanent regulator has to be built in approximately the position suggested in Map III. Neither the temporary regulator at Chara Chara nor the additional width of excavation to provide room for it can be regarded as contributing towards the scheme for permanent control of the lake over a range of three metres or more. It has already been pointed out in dealing with methods of provisional control contributing to the permanent scheme that even for a range from 81·00 down to 79·00, the excavation in the channel downstream would only be reduced by about one-tenth as compared with the scheme for controlling through a range of three metres. The natural river level at Kamforo with a discharge of 350 cubic metres a second is approximately 78·35, and it may be suggested that if a wide channel were excavated through the Upper Reef and neighbouring cataracts to provide



No. 29.—Northwards from West Point of Egirrbar Hills along Line of Proposed Channel.

enough water-way, the reservoir might be discharged to about 79·00, still allowing for a fall through the regulator and for a slope in the 2,500 metres of channel between Kamforo and the lake. Unless a drain is cut in the manner suggested in forecasting the method of carrying out the permanent works, excavation upstream of Kamforo would be more or less limited in depth by the water level there, and a very large cube would have to be removed over a great width to provide the necessary water-way. The objection is that almost none of this can be regarded as useful with a view to the deeper channel required for a greater range of control.

Works on Other Lines.

Examination of Map III may suggest other positions for the regulating works and channels. One of these is on a line connecting the Ifwadda Lagoon to the river near Kamforo, Photograph 11, and it might afterwards be connected with the lake by a channel along the line of the Ifwadda Lagoon. The lagoon is shallow and its mouth, where the regulator might be placed, is a long way from the deeper part of the lake, so that a great deal of costly excavation along it would be required. Another objection is that there is some relatively high ground between the lagoon and Kamforo, and altogether the quantity of excavation along this line would be very much more than along the river channel upstream of Kamforo, parts of which are either wide or deep and require no excavation.

Another line that may be suggested by the map is that connecting the lake just east of Bahrdar Giorgis village with the low-lying swampy ground running northwards from the bend between Egirrbar and Burifasas. The objections to this are that there is a good deal of high ground along this line, as may be gathered from the levels given on the map, and the floor of the lake is relatively high, so that only a limited amount of control would be possible, unless a considerable length of channel was excavated to connect with the deeper part of the lake. This excavation would have to be done under water, unless it was possible to unwater the line of the channel with the aid of *sadds* or sheet piling.

Utility of the Reservoir.

The suggestion mainly dealt with in this chapter proposes the control of the reservoir through a range of three metres below 81·00 and this seems to be the smallest amount worthy of real consideration. There may be preliminary works giving only a part of this control associated with disadvantages already mentioned as well as with others dealt with later in this section. Whatever the preliminary works, the prospect of a range of three metres or even more will certainly be borne in mind.

Transmission Losses.

A factor affecting the value of the lake as a reservoir is the amount of loss to which the discharge will be subject before it can be used for irrigation. First considering the long reach between Lake Tana and Roseires, the following table shows the quantities of water discharged from the lake and passing Roseires during the low stage of the river:—

TABLE XI.—COMPARISON OF LAKE TANA AND ROSEIRES DISCHARGES DURING THE LOW STAGE OF THE RIVER.

Period.	Lake Tana Discharge.	Roseires Discharge.	Lake Tana Discharge. / Roseires Discharge.
(1921)	Millions of Cubic Metres.	Millions of Cubic Metres.	Per Cent.
February	130	468	28
March	94	306	31
April	47	204	25
			Mean 28

As some loss is inevitable between the lake and Roseires, it follows that less than 28 per cent of the water passing Roseires comes from Lake Tana, or over 70 per cent of the water passing Roseires at present is due to perennial streams entering the Blue Nile between the lake and Roseires.

On June 22, 1920, a discharge of the Blue Nile was measured at Kutai ford, situated about one-third of the way from the lake to Roseires, and gave 28·6 cubic metres a second, the river being then about 10 centimetres above its minimum, while the discharge of the lake at that time was probably about 5 cubic metres a second. Moreover, Mr. Armbruster in a journey on the west bank from Agam Dildi to Debra Work in 1908 records crossing 25 streams with running water in the month of May. An examination of the Addis Abbaba rainfall records for 1908 shows that the rainfall was below normal to the end of June in that year and considerably below normal in May.

The river has not been explored along the whole reach and consequently any figure for the transmission loss can only be a rough estimate, but it seems unlikely that when the Tana dam is closed the river bed will be dry for any considerable distance below the lake outlet and it is therefore improbable that the transmission loss will be heavy. Ten per cent may be adopted as an estimate of its amount and thus 90 per cent of the water is assumed to reach Roseires when the Tana reservoir is discharging.

Considering the reach between Roseires and Makwar, the following table shows the quantities of water passing Roseires and Makwar in monthly periods during the low stage of the river in the years 1919, 1920, and 1921 :—

TABLE XII.—COMPARISON OF ROSEIRES AND MAKWAR DISCHARGES DURING THE LOW STAGE OF THE RIVER.

Year.	Period.	Discharges in Period.		Percentage Loss. Roseires–Makwar.
		Roseires.	Makwar.	
		Millions of Cubic Metres.	Millions of Cubic Metres.	
1919	February	464	429	+ 7·5
	March	318	276	+ 13
	April	162	146	+ 10
1920	February	393	416	— 6
	March	396	370	+ 6·5
	April	227	223	— 2
1921	February	468	439	+ 6
	March	306	295	+ 3·5
	April	204	164	+ 20
				Mean + 6·5

An inspection of the Roseires gauge diagram for 1921 shows that the gauge began to rise after April 15, and the consequent filling of the trough between Roseires and Makwar accounts for the relatively high transmission loss in that month. The mean value, 6·5 per cent, for this loss is of the order of accuracy of the individual discharges.

During the period when the Tana reservoir is discharging, the Roseires gauge will be raised by about 1·2 metres and increased losses will occur owing to the larger area of the river surface and the raising of the subsoil water alongside the channel between Roseires and Makwar. These extra losses are probably a smaller percentage of the extra discharge than are the normal losses of the normal discharge and the figure 5 per cent has been adopted as an estimate of the transmission loss in this reach. Thus it may be assumed that—

90 per cent of Tana reaches Roseires,
85 per cent of Tana reaches Makwar, and
68 per cent of Tana reaches Aswân.

If these figures are correct and 3,500 millions of cubic metres are discharged from Lake Tana and all passed down to Aswân, then the additional quantity arriving there will be about 2,400 millions of cubic metres or nearly equal to the present contents of the Aswân Reservoir. If, on the other hand, the water is used in the Sudan Gezîra, the Tana supply is equivalent to a volume of nearly 3,000 millions of cubic metres at Makwar. A comparison of these figures shows a considerable advantage in applying the water in the Gezîra and no doubt this will be done when the requirements of Egypt can be met from reservoirs on the White Nile and Bahr el Gebel.

Transmission Times.

It is thought that when the Tana reservoir is discharging at the rate of about 350 cubic metres a second, the water will take about eight days to reach Makwar and about thirty-two days to reach Aswân.

Method of Regulation.

Until it is decided how the water is to be used, it is impossible to say exactly how the regulation will be carried out. For purposes of discussion, the data have been applied on the supposition that the Tana regulator will be kept closed except during the period January to April. The results are shown in Diagram 15, which also includes the five-day means of the natural lake levels indicating the alteration caused by the reservoir. After the regulator is closed the water will continue to rise until the maximum level of 81·00 is reached towards the end of October, whereas under existing conditions the water reaches its greatest height about a month earlier. At the end of October the level of the reservoir will stand about 20 centimetres above the natural level of the lake, which by that time has fallen as a result of the outflow as well as evaporation. The reservoir level will then fall under the influence of evaporation alone and, as the diagram shows, at the end of December it will stand about 50 centimetres above the ordinary level of the lake at that time. It is assumed that the regulator will be opened at the beginning of January and water will be discharged at the rate of 350 cubic metres a second to meet demands for additional supplies in Egypt and the Sudan. This will proceed for a period of nearly four months and the lake level will fall at the rate of about 15 millimetres daily until it is nearly 30 centi-

metres lower than its normal lowest under present conditions. Towards the end of April the reservoir will be empty, the regulator will be closed, but the water level will continue to fall under the influence of evaporation until the end of June, when it will be about 50 centimetres below the corresponding level under present conditions. In July the lake will start filling up as the rainy season sets in and the cycle of operations will begin to be repeated. Such is expected to be the programme of regulation under average conditions.

The following table gives comparisons month by month throughout the year between the lake levels under average natural conditions and those that may be expected when it is used as a reservoir.

TABLE XIII.—COMPARISON OF NATURAL LAKE LEVELS WITH THOSE TO BE EXPECTED WHEN THE LAKE IS USED AS A RESERVOIR.

(Average Year.)

Date.		Normal Lake Levels, Present Conditions.	Reservoir Levels, Future Conditions.	Differences of Level.
				Centimetres.
July	31	80·03	79·56	— 47
August	31	80·74	80·40	— 34
September	30	80·94	80·86	— 8
October	31	80·79	80·99	+ 20
November	30	80·54	80·92	+ 38
December	31	80·31	80·80	+ 49
January	31	80·14	80·40	+ 26
February	28	79·97	79·99	+ 2
March	31	79·80	79·54	— 26
April	30	79·61	79·12	— 49
May	31	79·45	78·97	— 48
June	30	79·43	78·95	— 48

+ means that the level under reservoir conditions is above that of the lake under natural conditions.

— means that the level under reservoir conditions is below that of the lake under natural conditions.

It is seen that the level of 81·00, the highest level of the lake in ordinary years, will not be exceeded at any time under controlled conditions.

The result at Roseires of discharging the reservoir in this manner is shown in Diagram 16 and the river level there is seen to be raised by about 1·2 metres during the corresponding period.

The figures in the table are those set out in Diagram 15, which also shows how the water level would continue to fall if the regulator remained closed after the beginning of January. The emptying of the reservoir may be regarded as carrying the water level down until the trace on the diagram travels along a lower curve, where the fall is due to evaporation alone, and the position of this is indicated during the earlier part of April. The regulation of the lake, in fact, involves a fall in the water levels along some line connecting these two evaporation curves. The line may vary in position on the diagram according as the reservoir is emptied earlier or later, faster or more slowly. Whenever it is empty before the middle of June, a certain amount of water is shown as remaining to meet the evaporation. Towards the end of April this represents a volume of over 500 millions of cubic metres, which might be discharged if the regulator was allowed to remain open longer than we have outlined

above in the scheme of regulation. To discharge this additional volume is to be regarded as drawing on the next year's supply, for the water would continue to fall and a level correspondingly lower would be reached in June. The reservoir would have to fill from this lower level and the supply under average conditions would not be enough to allow the storage to be completely filled. The volume available at the beginning of the new season would be less by the amount discharged at the end of the old. Such are the reasons for regarding the routine storage as empty when the water level falls on to the trace of the lower curve in the diagram.

The Use of Reserve Storage.

The regulation outlined only relates to the routine storage in a normal year. It has already been pointed out that, with works at the outlet permitting control through a range of three metres below 81·00, there will be reserve storage to carry over the surplus from years of abundance to provide additional supplies in lean years. No attempt has been made to outline a scheme of regulation for such conditions, but there might be nearly 2,700 millions of cubic metres available in addition to the routine supply. In a season of poor rainfall, the amount of water reaching the lake might be considerably below the average and a proportion of the reserve would be required to make up the deficiency and allow the ordinary scheme of regulation to be maintained. In seasons of exceptionally poor supply such as those of 1914 and 1922, when still more water would be required, additional supplies from the reserve storage could be run off by opening the regulator earlier and allowing the discharge to continue until a later date. The works at the outlet in the scheme outlined have been calculated to allow of a discharge of 350 cubic metres a second down to a reservoir level of 78·00. A greater volume might be discharged for a time while the reservoir stands at higher levels and in such ways the routine storage as well as 2,700 millions of cubic metres of reserve could be added to the river during the season when it is most needed.

Regulation with Provisional Control.

This may be considered according to the extent to which the channel through the cataracts is excavated. If no excavation is undertaken and the sill remains as at present, the effect of regulation after the lake reaches its maximum level about the end of September will be as follows. From October 1, instead of flowing away freely in large volumes as at present, the discharge at the outlet would be checked by partial closure of the regulator so as to maintain the water at its maximum level, 81·00. This would continue until the regulator was completely closed about October 20, when the lake reservoir would be full and the discharge nil, whereas under present conditions at that time the lake would be standing about 15 centimetres below its maximum level. From October 20 the level of the lake would fall gradually under the action of evaporation until January 1, when its level would be about 45 centimetres above its usual level at that time under present conditions. On January 1, to meet the demand for supplementary supplies in the Sudan and Egypt, the regulator might be opened and the stored water gradually run off. The regulator would then be left open and the lake allowed to fill up under the action of rainfall. When it reached its highest level again the cycle of operations would be repeated. Much water would therefore be lost, as it could not be stored without exceeding the ordinary flood levels,

Moroever, the stored water could only be discharged at the same rates as the ordinary outflow of the lake at similar levels. It could not be discharged faster, consequently the whole of the water at levels above the present lake's lowest levels could not be run off.

Assuming, first, that the whole of the stored water is for Egypt's benefit and that it is held up at Lake Tana until January 1, corresponding approximately to the earliest date Egypt has drawn on the Aswân Reservoir, and that the regulator is then completely opened, the discharge would begin at the rate of about 250 cubic metres a second. This rate would diminish rapidly as the reservoir levels fall until by July 7, the date corresponding to the end of the shortage in Egypt, only 15 cubic metres a second would be passing through the provisional regulator. In all, about 1,300 millions of cubic metres would be discharged, corresponding to about 880 millions at Aswân.

On a second assumption that the stored water under these conditions is all for the benefit of cultivation in the Sudan Gezîra, that the regulator is fully opened on January 1 and that requirements cease in the middle of April, a volume of about 1,000 millions of cubic metres might be discharged from the provisional reservoir.

If no excavation is undertaken at the outlet, instead of discharging 3,500 millions of cubic metres, only about 1,900 millions would be available and of these but 1,300 could be discharged in time to be of use in Egypt or the Sudan. Moroever the lake would begin filling up again from a level 20 centimetres higher than usual (corresponding to the 600 millions of cubic metres that had not been run off) and would reach a level of about 81·10 if the following flood were an average one. Under such conditions, then, it would be impossible to prevent the lake rising slightly above its natural flood level every year.

If excavation is carried out so that the water may drain off to a level 50 centimetres below the present lowest level of the lake, it would enable the full discharge of the lake to be stored in a year of average supply. The amount of excavation necessary would depend on the manner in which the water is to be discharged. If it is conceded that requirements might be met by a large initial discharge falling off to almost nothing at the lowest levels, the quantity of excavation in the channel would be appreciably smaller than if a continuous discharge of 350 cubic metres a second were to be demanded. In this latter case, it has already been noted, p. 91, that the excavation in the channel would only be a tenth less than the amount giving full control of the reservoir down to 78·00 metres. It appears that provisional measures of control, including the construction of a temporary regulator, though they reduce the initial cost, will involve a greater total outlay. It has also, p. 91, been remarked that provisional measures do not offer the advantage of an earlier date of control and it does not seem that any of the alternatives could be achieved without work extending over two low-stage seasons. Consequently any claims to economy of time as compared with a scheme to give full control, should be very carefully scrutinized. Moroever, control down to only 79·00 metres would provide no reserve storage to safeguard cultivation in years of low supply.

Flood Protection.

Lake Tana's contribution to the volume of water entering Egypt at the greatest height of the flood is only about 160 cubic metres a second. The volume of an ordinary flood passing Aswân amounts to approximately 9,000 cubic metres a second, consequently the

lake contributes less than one-fiftieth of the volume entering Egypt at the highest stage of the flood. The water issuing from Lake Tana is clear and all the silt is brought by streams entering in other parts of the Nile valley. It can be definitely stated that manipulation of the reservoir at Lake Tana can only affect the flood in Egypt to an extent of about one-fiftieth of its volume, while it can have no effect at all on the proportion of silt.

Egypt will benefit directly but slightly from the Tana reservoir in regard to protection from the disastrous effects of continued high levels following very high floods. Even assuming that the high flood follows a year of abundant supply, that the reserve is completely filled and 30 centimetres of routine storage has not been required, the reservoir will not be full until about October 15, so that during the whole period previous to this, the regulator would have been closed and a discharge representing an average of about 350 cubic metres a second would have been abstracted from the natural flow of the river at Aswân. On October 15 under such conditions, the regulator would be opened to allow 500 cubic metres, the natural discharge of the lake to pass. The influence of this would reach Makwar on October 23 and Aswân about the middle of November, when the most anxious period concerning high water levels would be safely past.

Benefits to the Abyssinians.

The conversion of Lake Tana into a reservoir will be an advantage to the Abyssinians, as the water level need never be allowed to rise above about 81·00 and land along the shores will not be flooded even when rains are very abundant. The lowering of the level down to 78·00 will uncover rather more shore and when the lake is lowered to 76·00 it is expected that the uncovered belt of shore below the natural low stage level will be about one and a half kilometres wide. This will certainly reduce the swamps around the lake and make the neighbourhood much healthier. Some inhabitants may have to go rather farther to fetch water but many of them draw from streams and will not be affected. The construction of the control works for the reservoir will involve the spending of considerable sums of money, partly for mule hire or other forms of transport and also in the payment of labourers; and this increased circulation of money in Abyssinia cannot fail to benefit both the inhabitants and their Government.

Agreement with the Abyssinian Government.

The suggestions have been set out on the assumption that a stable agreement can be made with the Abyssinian Government, probably on the basis of the payment of an annual rental which shall not be so excessive as to upset the financial basis of the scheme. This factor, together with the estimated cost of the works, must be considered in regard to the value of the reservoir at Lake Tana. On the Egyptian and Sudan side there may also be an undertaking never to raise the water level above some level such as 81·30 metres, and a permanent mark showing this level might be agreed on by representatives of the two Governments before an assembly of the local inhabitants; a secondary mark could be made at Delgi, where the levels are well enough known and where there is also solid rock to base it on.

On the Abyssinian side, besides permission to control the waters of the lake by means of works at the outlet, the agreement should arrange for a sufficient area to ensure safety and control of the works at the outlet and the channel downstream. This would extend from a kilometre north of the outlet, include all the islands at the outlet and belts of land 500 metres wide along the shores and both banks of the river, to a point one kilometre downstream of the falls at Arafami. An undertaking should also be given that the inhabitants occupying the land when the agreement is reached would have the first claims to lease under the new conditions. The means of access to the lake, the site of a depot at Delgi or elsewhere and rights to remove sand or other material from the shore of the lake or its neighbourhood should be covered by other clauses of the agreement.

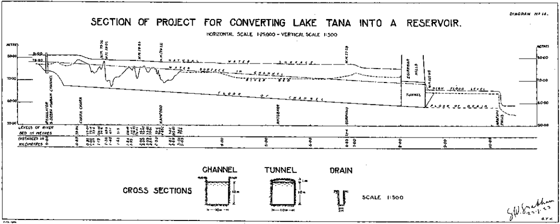
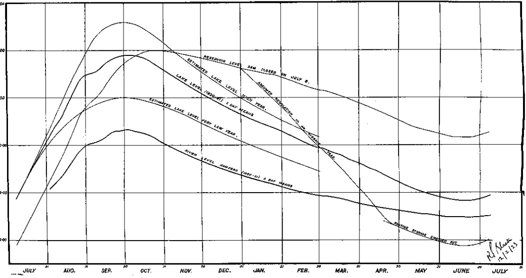


DIAGRAM No 14.
SECTION OF PROJECT FOR CONVERTING LAKE TANA INTO A RESERVOIR.
HORIZONTAL SCALE 1:25,000 - VERTICAL SCALE 1:500
METRES
80·00
70·00
60·00
50·00
NATURAL WATER SURFACE
WATER SURFACE IN CHANNEL
RIVER BED
FLOOR OF CHANNEL
EGIRRBAR HILLS
TUNNEL
HIGH FLOOD LEVEL
FLOOR OF DRAIN
REGULATOR
S. DEBRA MARIAM CHANNEL
CHARA CHARA
KANFORD
ANTOBARR
GURRANAS
ARATAFI FALLS
LEVELS OF RIVER BED IN METRES
DISTANCES IN KILOMETRES
4·00
5·00
6·00
7·00
8·00
9·00
10·00
CROSS SECTIONS
CHANNEL
TUNNEL
DRAIN
SCALE 1:500

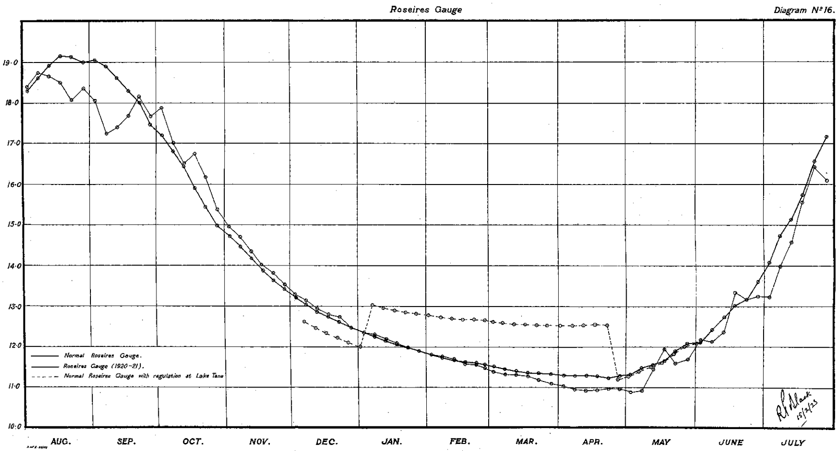
LAKE, RIVER AND RESERVOIR LEVELS WITH ASSUMED REGULATION IN AN AVERAGE YEAR.

Diagram No. 15.



DOWNSTREAM EFFECT OF ASSUMED REGULATION AT LAKE TANA

Diagram Nº 16.



R J Black 15/2/23

APPENDICES.

APPENDIX I.—CONDITION OF THE INHABITANTS.

The remarks in this chapter are not intended to be in any way exhaustive but merely to indicate some points that bear on expeditions such as the Tana Mission and perhaps may have some influence when an organization for constructing works at the outlet of Lake Tana has to be arranged. The reader in search of comprehensive information about the people of Abyssinia and their history may be referred to the handbook (1) prepared under the direction of the historical section of the Foreign Office. Besides giving a brief but fairly complete account of the whole subject, it contains a useful list of authorities. Among the later writers dealing with the neighbourhood of Lake Tana, the accounts given by Dr. A. J. Hayes (2) and by M. Rava (3) may be recommended as giving good ideas of conditions of travel during the dry season. Conditions during the wet season seem to have escaped adequate attention, perhaps because most travellers' visits have occurred during the finer parts of the year. Even Abyssinians avoid travelling during the rains unless it is absolutely necessary. The streams are swollen, and have soft muddy banks difficult for transport animals. The ground is sodden, there is much rain and heavy dew, and dampness is the prevailing condition.

Health.

There are too many marshes near the outlet of Lake Tana for the neighbourhood to be considered healthy. In July and August 1920, there were relatively few mosquitoes, and even though a considerable proportion of them was anopheline, the health of the camp continued good until towards the end of September. The number of mosquitoes increased and during October, and in November there was a considerable amount of fever; in fact, at one period during the month, the effective strength of the camp was reduced by nearly 50 per cent. The incidence of the fever was quite as great among the Abyssinians as among those who had come from the Sudan and this may be explained by the fact that most of those employed belonged to higher parts of the plateau. M. Minas Kherbeguian's camp was close alongside that of the Tana Mission. He had an extremely trying journey from Addis Abbaba during the rains and arrived at Bahrdar Giorgis when fever was most prevalent. Almost the whole of his party suffered severely and two men died. The Tana Mission had better fortune, but three men died out of Major Colquhoun's party, which came up from Gallabat and returned after handing over the equipment and stores at Dangila. These deaths may be attributed to sickness contracted in the low country the party had to traverse and, including these, the Tana Mission lost altogether four men from disease during a period of nearly thirteen months. There were one or two extremely

(1) No. 129. "Abyssinia," publ. H.M. Stationery Office, London, 1920
(2) "The Source of the Blue Nile," London, 1905.
(3) "Al Lago Tsana," Missione Tancredi, Rome, 1913.

bad cases of fever, but fortunately, with care, they recovered enough to be sent to their homes on the higher part of the plateau, where they soon regained strength and generally returned, after a few weeks, completely restored to health. No tests were made, but having regard to the correspondence between the mosquitoes and the incidence of the fever it has been regarded as malarial and this was borne out by the manner in which the sufferers responded to quinine treatment. At the time when mosquitoes were most abundant it was quite frequent to find men with an eyelid so swollen as to completely close the eye. Fortunately both eyes were rarely affected at the same time and the swelling soon subsided, passing away in the course of a couple of days. It appears that this trouble was due to mosquito bites and it was altogether absent during the dry season.

A selection of mosquitoes from Bahrdar Giorgis was sent to the British Museum and Mr. F. W. Edwards recognized among them the following kinds :—

Anopheles mauritianus, Grandpré.
A. squamosus, Theo.
A. ? longipalpis, Theo.
Mansonoides uniformis, Theo.
Culex quasigelidus, Theo.
C. ? fatigans, Wied.

It is probable that there are many other kinds and the subject would repay systematic study.

The prevalence of parasitic worms among the Abyssinians, due to their predilection for raw meat, is remarked on by almost every writer dealing with health in the country. The dried inflorescence of *Brayera anthelmintica*, Am. *Kosso*, is used to make an infusion which is taken as a remedy for the malady, and a day's holiday for the purpose is not an unusual request. The Abyssinians seem to be afflicted also with a great variety of parasitic insects and the traveller should be on his guard against fleas, bugs, and lice, but though cleanliness is a great safeguard, these insects may occasionally find their way into a European's proximity on satchels or camera cases which have been carried by servants. Scabies is also very frequent.

In the winter time there were certain places, usually where the drying grass was fairly long, where there were numbers of small ticks. Almost microscopic in their size, they found their way through puttees and their attacks were usually limited to the legs. Their presence was as a rule only noticed about 12 or 18 hours after they had become attached, and they inflicted a most irritating bite. It seemed to make no difference whether the tick was iodined, vaselined, or merely picked off as soon as it was discovered. The irritation increased, reached its height about two days later and passed off at the end of five days or a week. The place was not completely healed until a fortnight after the tick had begun its attack. and during the early stages the inclination to scratch the spots was almost irresistible, Scratching only made the places worse, and one boy who was badly bitten managed to introduce some kind of infection so that they ulcerated. The infection spread to other parts, including his face and hands, and he was only cured by taking a course of baths at a hot spring. Some of the ticks were sent to the British Museum, where Mr. V. Hirst pronounced them to belong to the genus Amblyomma, but was unable to determine them specifically owing to their being only in the larval stage.

The climate of the shores of Lake Tana is cool enough to render unnecessary any stringent precautions against the effects of the sun's rays.

Culture.

Education.

The priests read and write and are versed in theology. They maintain schools associated with many of the churches, where boys are taught to read and write, and these children take certain parts in the church services. There is no education apart from these church schools, but even so, there is a fair proportion of people who can read and write. There seem to be almost no books and the art is limited to letters. The Abyssinian system of numerals seems to be cumbersome, like that of the ancient Romans.

The people are extremely suspicious and credulous, and the rumours that circulate are often quite extraordinary. To obtain water levels it was the Mission's custom to measure the depths of water on certain rocks. This proceeding gave rise to a rumour that sticks were being put in to poison the water and prevent it from rising. No reason was ever gathered as to why it was thought the water was being poisoned or who would be affected, but the fact remains that our objects in measuring water levels continually, even if explained, could hardly be understood by the peasants and they interpreted it in their own way. The people near the outlet, however, quite appreciated the reason of our interest in the supply of water from the lake and there were all sorts of quite baseless rumours about the kind of control works proposed, which increased in magnitude as the stories spread farther and farther. On one occasion, stopping to write notes about streams crossed in the course of a journey, this was immediately commented on to the effect that we wanted to take away their rivers and it was asked what would their cattle drink. No one, however, understands better the value of such rumours than the Abyssinians themselves, particularly the great chiefs, and there was never any hint that the least importance was attached to them in such quarters, though it was found that they and others were well known. It is clear, however, that travellers should be extremely careful to give as little cause as possible for the spread of rumours. No doubt the suspicions which foster the spread of such rumours are associated with the national sentiments and their resentment at the idea of any outside interference with their domestic affairs. Strangers who have sojourned in Abyssinia must sympathize with these sentiments and share the hope that the Imperial Government may be able to foster liberal education and lead the people forward to enjoy the fruits of liberty and civilization.

Religion.

Most Abyssinians are monophysite Christians and the churches standing in groves of trees are centres of the people's life. The priests have great influence and besides ministering to the spiritual welfare of the people, they control certain lands and also lend money at interest. Though their education is clearly very limited when measured by European standards, they are among the most cultured of the people, and their friendship and sympathy deserve to be cultivated. They may be of the greatest use in arbitrating if differences of opinion arise. Abyssinians fast regularly on Wednesdays and Fridays during most of the year as well as at prescribed seasons. At such times they rigidly abstain from eating animal food and this accounts for the extensive cultivation of seeds to supply oil for consumption during the fasts.

There is a small proportion of Mohammedans and a little village colony exists at Bahrdar Giorgis, but though they live close by, they seem to be quite apart from the Christians and there is little communication between them. Abyssinians often regard Europeans as being Mohammedans, since travellers neither fast nor wear the *matab* of black silk cord around their necks, and frequently eat meat and food prepared by Mohammedan servants. Abyssinians are far too polite to give ready expression to such views, but they sometimes drop out unawares, as when a small chief hearing for the first time the reproduction of the voice by a gramophone commented that the Mohammedan whip reached far, evidently meaning that followers of the Prophet had great inventive faculties. When Abyssinian guests are entertained, food should be prepared by Christians and Mohammedan servants should, if possible, be excluded from waiting on the company.

LAW.

The Abyssinians have considerable taste for litigation and when a case arises a court is soon called together and proceeds to hear the arguments of both parties. The people are practised at this kind of thing and the oratory often appears as if it would do justice to far more important matters. The traveller will do well to avoid becoming involved in any of these cases, and it is in such matters as when one of his mules strays on to some cultivation that he may appreciate the services of a good interpreter to act as intermediary.

CURRENCY.

The Maria Theresa dollar has already been referred to as being the only coin accepted in the neighbourhood of the lake. It is dated 1780 and is about the size and weight of an Egyptian P.T. 20 piece or a British 5/- piece. These coins have been specially minted for use in Abyssinia and their value changes according to the price of silver. In the Sudan estimates are based on a factor of 3·3, the price of silver in pence in London being multiplied by this, allows for alloy, etc., and gives approximately the value of the coin in milliemes. The price in Addis Abbaba is said to depend on that of the rupee at Aden and was generally rather lower than that ruling in the Sudan treasuries. Within six years it has varied from 7 to 27 piastres in value. Menelik introduced his own coinage, including a dollar similar in size and which passes as equivalent to the Maria Theresa coin. It was accompanied by small change, including piastres at sixteen to the dollar, and quarter and half-dollar coins, but their use is limited to the neighbourhood of the capital and none circulate near Lake Tana. Cartridges and cumbrous bars of salt serve as change at different values, generally about three or four to the dollar, and small domestic purchases are conducted by barter.

All this has a very direct bearing on any proposal to construct works at the outlet of Lake Tana, as considerable amounts of local currency would be necessary to pay labour and transport. If the construction of works were to be sanctioned at the present time it is believed that enough dollars could not be obtained to finance the works, and in view of the extreme conservatism of the people it would be difficult to rapidly introduce any other currency that might be sanctioned by the Abyssinian Government. The matter will have to be very carefully considered and no doubt the spending of large sums, such as the construction of control works will involve, may afford opportunity for co-operating with

the authorities in introducing a stable and convenient currency. The alternative may be to arrange with the Austrian Goverment, which is quite ready to mint fresh Maria Theresa dollars.

Recreations.

The number of holidays in the Abyssinian calendar is often regarded as a serious drawback in organizing labour. The Tana Mission found no difficulty in this respect during the period 1920–1921, but great festivals such as Christmas, Easter, New Year's Day, and the Feast of the Cross were observed and all men who could be spared were given the holidays. It would no doubt be necessary to recognize such holidays when any large quantity of Abyssinian labour is employed. The trouble of losing labour on smaller feasts and fast days might be most easily circumvented on the principle of a daily wage and "no work no pay."

Turning to actual recreations, it may be recorded that after the rains, until about the end of December, the men and big boys of the village used to come and play a sort of hockey on the plain near the camp. There were no defined goals and there did not appear to be any sides, but a considerable crowd joined in and played for a while with great energy. The ball was plaited from raw hide. At the camp the men used to sit and talk or sing around a fire in the early part of the evening. The singing was of the nature of chanting, following the cadences used at churches, which seems to be the general type of Abyssinian music. It is certainly primitive, and though monotonous to the European, there are no discords. There was one musician in the camp who played a fiddle quite dexterously, but for the most part, as elsewhere in Africa, the men were content to strum the same notes on a few strings with an occasional change in the order, for hours together. The notes, however, were always quite carefully tuned.

Industries.

Transport.

Mules, donkeys and to a less extent ponies are used as pack animals and it may be said that there are no other means of transport. Small parcels may be carried by men but porterage cannot be regarded as a common method. The animals, both donkeys and mules, are all quite small, consequently the size of the loads is limited, but they all travel well over rough hill tracks. This matter is dealt with further in Appendix IV.

The only transport on Lake Tana is by means of the canoe-shaped papyrus rafts known as *tankwas* and shown in Photographs 7*a* and 20. They consist of an outer, canoe-shaped sheath, Photograph 12, made of papyrus stalks carefully bound together, and within it is placed the *jiff-jiff*, a large bundle of papyrus stalks tied so as to have a flat upper surface on which passengers can sit. The sheath makes no pretence at being water-tight and the longer the craft is used the more waterlogged and less efficient it becomes. When in daily use, they last about three weeks and the cost of one capable of carrying six or eight people is about three dollars. Bladed paddles of any kind are unknown and the craft are paddled with long reeds, surprisingly good speeds being attained. *Tankwas* are used between villages, as for instance between Bahrdar Giorgis and Zegi, being both quicker and

safer then going by road. They are also employed extensively to carry coffee, destined for the Sudan, from Zegi to Delgi. At present there are no boats on the lake, but there can be no doubt that when they are provided they will afford most useful and expeditious means of transport across its waters.

TRADE.

Trade is carried on by parties of men who travel about the country from one market to another with their goods on pack animals. There can be no doubt that the circulation of trade in Abyssinia is much hindered by the existence of a number of toll gates where dues are collected from all who pass. These tolls are farmed out and provide the emoluments of chiefs. Apart from the tolls, routes in Abyssinia are often unsafe and a few individuals with loaded pack animals are quite liable to be attacked and robbed. The consequence is that traders form parties and travel together for mutual protection. Individuals may join and accompany the traveller's party over short distances for the same reason.

There were two or three Greek traders in the neighbourhood of Lake Tana, but possibly the last will have departed before the publication of this report. They were formerly interested in egret feathers, but this trade has fortunately been stagnant since most European countries prohibited their import. The Greeks are, however, enterprising traders and some will certainly be ready to open small stores near the outlet whenever conditions may appear favourable.

Markets are held weekly at many places in Abyssinia and form important centres of concourse and trade. Wednesday is the day at Bahrdar Giorgis and during the dry season, when the roads are easy, people come in from miles around.

LABOUR.

With the proposal to construct works at the outlet, questions as to the supply of labour naturally arise. The experience of the Mission suggests that ample supplies of quite useful unskilled labour may be available, provided the people are dealt with tactfully. Many Abyssinians go to soldier in the Sudan and Eritrea and it is said that the Italians were able to obtain considerable supplies of Abyssinian labour while constructing the railway from Massaua to Asmara. The Abyssinian is certainly not partial to heavy manual labour, but if works are undertaken, the advantages of fostering the supply of workmen so that large sums paid in wages may remain in the country will be fully appreciated by the ruling chiefs, who may be relied on for active assistance.

HERDS, FLOCKS AND LIVESTOCK.

There are considerable herds of cattle in the neighbourhood of Lake Tana and the Fogara and Dembia plains, especially, are regarded as affording good pastures. Sheep do not appear to thrive near the lake but are abundant on the higher parts of the plateau, from where they may be fairly easily obtained. As soon as it was found that there was a demand for sheep at the Tana Mission camp, traders would occasionally appear with a few for sale and the result was that a supply of mutton was always available. The domestic fowl is small but abundant, and there was rarely any difficulty in obtaining supplies of

birds and eggs, but latterly it seemed that the supply in the immediate neighbourhood was depleted. Fowls and eggs were sold at the rate of 16 and 80 respectively for one dollar.

Near Bahrdar Giorgis the cattle are sent out to graze in the daytime in charge of a few children. When they come in, in the evenings, their owners meet them to milk their respective cows, so that each evening a procession of men, women and children with gourds was found either going or coming. The calves were herded separately during the day but were brought each evening to suck for a time after milking was finished and later were collected again to spend the night safely indoors. During the rains the cattle were herded for the night on the open plain near the Tana Mission camp and there they remained through drenching storms in charge of a couple of men beneath sedge rain-proofs. Protection from mosquitoes may have been one of the principal reasons for herding the cattle in the open. Later on, when conditions became drier, the cattle were moved away and during the dry season they were kept at night in a fenced space near the village.

Natural Products.

Perhaps the most important of these are honey and beeswax. In the early part of the rainy season swarms of wild bees appear and these are captured in great numbers by the people, who put empty hives in likely-looking trees to attract them. The hived swarms are subsequently sheltered in specially constructed places near the owners' houses, then towards November, when flowers are almost over and there is little food for the bees, the honey is taken and the bees for the most part are destroyed. The honey is excellent, with a distinct flavour of the Coreopsis flower which provides a large proportion of the nectar. It is generally marketed in a dirty condition, full of wax and dead bees, but is an important commodity, the greater part being fermented to make the national drink *tej*. It is also used for sweetening in place of sugar, which is not obtainable in local Abyssinian markets.

Thatching grass has to be collected with care and sometimes particular areas are specially protected from fire. Mariam Sar close to Bahrdar Giorgis is such a place. For the rest, the long grass is fired as soon as it is really dry and the roots soon sprout and provide fresh grazing for the herds. *Kosso* has been referred to and is found in markets, and the wild ginger, *Zinziber officinale*, is also collected for sale.

Arts and Crafts.

It cannot be said that there are any manufactures near Lake Tana. There are a few crafstmen and perhaps the most important are the tanners and leather workers, who prepare leather, make bags, etc., and also make the raw-hide thongs used in securing loads on pack animals and as substitutes for rope. A little poor string is made from papyrus, but the Abyssinians do not seem to make rope. An excellent homespun cotton cloth is woven from cotton traded in the markets and this provides a large part of the clothing. It is thick and warm and makes excellent wraps or *shammas* to protect from the cold. There are a few blacksmiths to make and repair the iron parts of hoes and ploughs and some pottery is made. Basket work is plaited from palm leaf fibre. There seems to be a class of itinerant craftsmen who do the much more skilled work seen in churches, where the doors, windows and roofs are often quite well made. The ordinary villager's house is a thatched hut, where he is quite content to live in squalor under the same roof as his donkeys or mules and cattle that require particular protection.

AGRICULTURE.

Agriculture is the most important pursuit of the people. The soil over the whole of the Abyssinian plateau under the influence of the climate is very fertile and the rainfall is enough for nearly all crops to be grown without resort to irrigation. Tillage sometimes begins quite soon after one rainy season in preparation for the next, as if to prevent the growth of weeds and conserve soil moisture. Bulls are used in ploughing. The same land is not cultivated continuously, but after being cropped for three or four seasons it is allowed to lie fallow and other ground is broken. This system seems to involve an area remaining fallow nearly twice as large as that under crop. The consequence is that only about one-third of the land around villages is cultivated, while the rest is devoted to pasture. Near Addis Abbaba, turf on freshly broken ground was seen to be collected, burnt and the ashes ploughed in.

The following is a list of the principal crops and indicates what kind of supplies may be expected. The authorities at Kew have given assistance by supplying some scientific names.

Maize.—There are fair supplies.

Great Millet.—Sorghum, Am. *mashilla,* Ar. *durra,* is grown but does not appear to be in favour.

Abyssinian Millet.— *Eragrostis Abyssinica,* Am. *tef,* is a small, almost sand-like grain, either white or brown in colour, and probably forms the most important article of diet in the country. Dr. A. W. Hill, F.R.S., Director of the Royal Botanical Gardens at Kew, states that this cereal has been introduced into South Africa and there are now 500,000 acres of it in the Transvaal, all as a result of seed originally obtained from Abyssinia.

Small Millet.—*Elusine corracana,* Am. *dagussa,* Ar. *telabun.* Only the white variety is used for food, but both it and the black kind are extensively employed in making *talla,* the local beer.

Wheat.— Am. *sindie,* is a general term and *saintie, silembia,* and *adja* are among the varieties recognized. Hardly any is grown in the neighbourhood of Lake Tana, but the grain is brought to the markets from higher parts of the plateau. A few samples were sent to Prof. Biffen, who remarks that many of the types cultivated in Abyssinia are utterly unlike those in any other part of the world, and it seems not unlikely that some races of wheat may have originated there. He recognizes the *adja* type as an exact counterpart of some IXth Dynasty Egyptian wheat found by Sir Flinders Petrie.

The endosperm of some *sindie* proved to be unlike any other that the Professor had met with, and the *saintie* was found to be a mixture of types, including the only purple grained wheat known. The various types obtained are being grown and experimented with at Cambridge and it is clear that if a few samples from one neighbourhood contain so much of interest there is likely to be much else that is new among wheats, especially in other parts of Abyssinia. The matter is of practical importance since, by crossing, it may be possible to improve existing strains.

Barley.—Am. *gabs*, is grown on the higher parts of the plateau up to altitudes of over 3,000 metres and samples sent to Cambridge proved to be of interest on account of rust-resisting qualities and their being cultivated at such great altitudes.

Onions.—Supplies could always be obtained.

Nigella Sativa.—Am. *tukur abasoda*, Sudan Ar. *kamun azrag*, Egyptian Ar. *haba soda.*

Cabbage.—Am. *gomman*, a weedy variety but quite good eating, obtainable during the rainy season.

Cotton.—Grown in warm places such as the valley of the Tul.

Flax or linseed.—*Linum usitatissimum*, Am. *talba*, is grown with the object of preparing oil from the seed and is not used for fibre. White and red varieties are distinguished respectively as *nach talba* and *kei talba*, and the former, when pounded and mixed with water, is esteemed as a medicine or nutritious drink.

Vines—are sometimes referred to by writers on Abyssinia and it appears that the plants were destroyed by oidium about 1855. No trace of cultivated vines was seen but some wild varieties exist.

Coriander Seeds.—*Coriandrum sativum*, Am. *dimbilal*, Ar. *kusbara.*

Peas.—Tough skinned, dark coloured varieties are grown on the higher parts of the plateau.

Beans.

Chick Peas.—*Cicer arietinum*, Am. *shimbra*, Ar. *kabkabek*, are quite extensively cultivated.

Fenugreek.—*Trigonella foenum-græcum*, Am. *abash*, Ar. *helba.*

Potatoes.—Am. *dinnich*, are not cultivated on the shores of the lake, but supplies were always abundant from the higher parts of the plateau at altitudes above 2,000 metres. The tubers are excellent eating but small.

Red Pepper.—*Capsicum annuum*, Am. *barbarie*, Ar. *shatta*, is cultivated with great care near the shores of the lake and elsewhere. The seed is sown before the end of the dry season and the young plants are irrigated artificially. After the rains begin, they are planted out in regular fields and the quantities grown and consumed by the Abyssinians are surprising to Europeans. It is used to flavour almost all kinds of food and especially to make sauces for raw meat, to which there is great partiality.

Tobacco.—Abyssinians do not smoke and the plant is not cultivated.

Tomatoes—are not cultivated or eaten by the Abyssinians, but there is a small wild variety which can be obtained during a considerable part of the year and which forms a welcome addition to the traveller's menu.

Basil.—Ocimum basilicum, Am. *zagagbi*, Ar. *rihan*.

Coffee.—Coffea arabica ; a little is grown near Bahrdar Giorgis and it is extensively cultivated and exported from the Zegi district. The shrubs are protected by the shade of trees.

Pumpkins—are obtainable during the rains and for some time after.

Rantil Oil Seed.—Guizotia abyssinica, Am. *nug*. Tall and short varieties of the plant are extensively cultivated for the seed, from which oil is obtained.

APPENDIX II.—NATURAL HISTORY.

Flora.

The Cataract Weed.

This is certainly one of the most interesting plants associated with the outlet, only growing where there are rocks associated with rapid currents and thriving in the violent rush of cataracts. The rocks of the cataracts were quite clean in August 1920 before the water rose over them, but when the water fell to similar levels after the flood they were covered with a dense growth of the weed. The plant has roots or suckers, perhaps with "haptera" for adhering to rocks, and the stems, about the thickness of lead pencils, 6 millimetres, show dischasial branching, forming a thick mat on rocks in the rush of the cataracts. This is shown in Photograph 18. The stems bear little dark green leaves, probably scales morphologically, making it appear as if covered with an alga. As the water surface falls and approaches the ends of the shoots, flowering spikes are formed and these eventually rise into the air, where the flowers open. The spike is about 5 or 6 centimetres high, stands vertically and is covered with minute pink flowers. The calyx is green and bract-like; the corolla is bell-shaped with pink lips, the stamens are four and the ovary is superior, bilocular and contains many ovules. As the water continues to fall, the green scales dry, revealing a tangle of pink stems which in their turn also dry, become broken and appear to fall off the rocks. Probably the early rains of the following season wash off all that remains of the old plant and leave the rocks clean, as we saw them before the flood rose in August. It is clear from the position of the plant that it must derive its nutriment almost entirely from the water flowing around it. It began to appear when the lake fell to about 80·40 and the greatest growth was exposed at about 80·20. It was then seen that there was less at lower levels and rocks covered with about 40 centimetres of water were practically free from the weed. No doubt this distribution varies according to the height of the flood, but it must also depend on the distribution of the seed during the preceding season. When the stems are exposed the little capsules ripen and burst and the seeds are probably blown about by the wind. Specimens were sent to the Royal Botanic Gardens at Kew where Dr. O. Stapf identified the plant as *Rotala repens*, Kœhne (Lythraceæ), and the following remarks are taken from his memorandum. There were no previous specimens in the collection at Kew, unless they had been entirely misplaced, and those from Lake Tana were regarded as very interesting additions. The plant was originally described as *Rhyacophila repens* by Hochstetter, then as *Quartinia turfosa* by A. Richard and finally referred to the section Nimmonia (originally proposed as a new genus) as *Rotala repens* by A. Kœhne, the monographer of the family. It represents a type quite singular within the genus more or less mimicking certain Podostemaceæ and species of Utricularia which grow under similar conditions.

Dr. Stapf proceeds to record that A. Richard, evidently quoting from a note by Quartin Dillon who collected the plant in Abyssinia, says, "*la plante flotte quelquefois à la surface des eaux, sur laquelle elle forme des touffes d'un rouge purpurin ou elle s'étale sur la vase mise à nu par le retrait des eaux.*" Schimper also found it near Docheli, Sanna, in Abyssinia. The memorandum remarks that the structure of the testa of the seed probably explains

their becoming attached to the boulders when the water falls and whilst their surface is still wet. If a seed is put into water, after a short time hairs are seen to grow out of the originally smooth testa. These hairs may attain a length equal to half the diameter of the seed; they have clavate tips and are covered, as it seems, with mucilage, which would glue them down to any wet body where they may alight. Dr. Stapf concludes by remarking that information is still required on certain points and among them are questions as to how long fresh seeds take to shoot forth hairs when wetted. When placed on a wet boulder, do they become sufficiently fixed not to be washed away again, and when fixed, how long do they take to germinate? The hairs may be seen with an ordinary pocket lens.

Stunted-looking forms of the plant with characteristic spikes of flowers may be found on rocks where there is less current than in the cataracts, but the ordinary reaches of the river are quite free from the growth. The remarks quoted by A. Richard to the effect that the plant may float at the surface of the water or spread over mud do not at all correspond with its conditions of growth at the outlet of Lake Tana. There, it is found only on rock and never on mud, and in fact the positions where it flourishes and attains its most luxuriant growth among the cataracts are associated with such violent rushes of water that no mud could persist. Nor does the plant show buoyancy to be described as floating in the water, but it forms mats that are pressed against the rocks by the velocity of the water. Dr. Stapf's notes about the hairs enable the distribution of the plant to be understood. It does not occur even on the rocky shores of the lake, but its seeds evidently succeed in attaining the uppermost parts of the cataracts, where it would seem that the great tendency must be for them to be carried downstream by the rush of the water. Evidently the wind and perhaps the feet of birds frequenting these rocks must be responsible for the distribution of the seed, and it germinates and grows only where suitable conditions are found. Any carried on to rocks on the shores of the lake or in quiet reaches of the river is lost, while that finding its way to rocks in cataracts and rapids grows almost in proportion to the current of water to which it is subject. It seems that the seed must be able to survive a number of wettings and dryings before it finally germinates. The rocks are well rained on by the early showers and in the intervals of sunshine the dark surfaces not only dry but attain temperatures that might be expected to kill any seed or newly germinated plants. Yet it survives all this and is ready, provided a suitable spot has been reached, to grow when the flood eventually rises and submerges the rocks. It seems obvious too that the seeds cannot be carried on to submerged parts, consequently the lowest water levels set a definite bottom limit to its distribution, and this proved to be the case, for the rocks still submerged at the time of the lowest levels were free from the weed. Unfortunately the lower limit was not well enough defined to permit estimates to be made of the low stage level of the preceding season on which it appears to depend. The most luxuriant growth seems to occur where the rocks bearing the plant are submerged to depths of about 80 centimetres. Possibly at greater depths conditions of light become unfavourable and the number of survivors gradually diminishes as the depth and period of submergence increases. Such factors would account for the distribution observed.

When the lake rises the water passes out over clean rocks, but when the lake falls they are partly covered with the growth of weed; the sills of the cataracts may be regarded as having been raised and the discharges at certain levels are less when the lake is falling than when rising. The extent of this effect has been dealt with in Chapter IV and it is clear that it must increase until the water falls to about the level of greatest growth, while

below this it gradually diminishes, ceasing at the time of lowest levels, when the water always passes over clean rocks. This has been borne out by a study of the discharge data, leading Mr. Black to conclude that the effect of the weed was greatest in 1921, when the lake level was 80·10. The weed was found on all the cataracts for a distance of at least 15 kilometres below the outlet and the water levels in the reaches between must be correspondingly affected, so that rather higher levels may be expected during the falling stage. The distance to which the growth of the weed extends downstream is not known. Near the lake the river water is clear, but it becomes turbid as tributaries enter and add silt, and this may set a limit to the distribution of the plant.

PAPYRUS.

This plant is of considerable importance in regard to the swamps on the White Nile and Bahr el Jebel and the following notes on its growth and distribution near the shores of Lake Tana may be of interest. The extent of papyrus marshes near the outlet has been referred to in Chapter IV and the plant may be regarded as covering a considerable proportion of the swampy ground shown on Maps III and IV. During the dry season the water subsides and in many places the rhizomes of the papyrus are left on dry ground sometimes formed of only a thin layer of soil on rock. It is evident that there is no need for the rhizomes to be permanently under water, though very often the marshes have a margin on the water. There are, however, plenty of places where the papyrus becomes quite isolated from any surface water during the dry season. Possibly in these its growth is maintained by ground water, for even though there is no sign of it on the surface, the plant never occurs at levels above those that might be fed either by the lake or the river. Ground that is thoroughly swampy during the season from rain water alone does not support papyrus. It is to be recognized that the idea of papyrus growing in floating masses seems to be quite contrary to fact, for wherever the growing plant has been observed, both at Lake Tana and on the White Nile, it proved to be firmly rooted. It is only when the rhizomes are firmly held that they can maintain the aerial stalks in the characteristic upright position. The distribution of the plant on the White Nile seems to be confined to reaches where there is only a small annual range of water levels and doubtless the limited range at Lake Tana is also favourable to its growth. There must however be other factors, as no papyrus was observed on the eastern and northern shores of the lake. Along these there are marshes that appear suitable, but they only bear smaller varieties of sedges and grasses. The people have no means other than the papyrus *tankwas* of crossing the water, and as remains of such craft were found along those parts of the shores, it is clear that they must be brought from the papyrus-bearing regions. This point was remarked at Delgi, where *tankwas* were said to be obtained from Zegi. It will be extremely interesting to watch the effect of the conversion of the lake into a reservoir on the growth of papyrus. The water will not be allowed to rise as high as it now does, but there will be an increased range and it will fall to a distinctly lower level. The means of making *tankwas* may become less abundant, but the reduction in size of the marshes will be a decided blessing to the people, for whom they are unhealthy neighbours.

The drying up of some of the papyrus swamps during the dry season has been referred to, and though the stalks and shoots still appear green they become dry enough to burn. Towards the end of the dry season considerable stretches near the outlet were burnt, but the rhizomes remain and fresh shoots began to appear soon after the fire. Large areas of papyrus in the *Sadd* Region of the White Nile are burnt almost annually under similar conditions.

Other Vegetation of the Lake Shores.

The exposed parts of the rocky shores of the lake near the outlet are free of vegetation near water level and this is no doubt due to the action of waves. The rock slopes down to a clayey bottom, covered with weed in the shallower parts, where water depths of from 1 to 1·5 metres remain during the low stage season.

The vegetation on land can only be briefly referred to. There is very active growth during the early part of the rains and the landscape is green except for some flowering trees. In September before the rains are over, the grass begins to wear a distinct yellow colour. The hillsides are then golden with the flowers of *Coreopsis prestinariæformis* (Vatke), and bees are at the height of their activity in collecting nectar. There are purple patches of clover flowers among the grass, the big, thistle-like *Acanthus arboreus*, Am. *kuchachilla*, occurs in two distinct varieties, one more branched with brick-red flowers appearing earlier, and the other with tall straight stems and purplish red blossoms continues the display of colour. By November this is all over and in December the herbage withers, dries and begins to be burnt. Nearly all the trees lose their leaves and the bare branches rising above the dry grass give the landscape an almost winter-like aspect. Large Ficus trees, Am. *warka*, are among the first to regain their foliage. When the grass is burnt, the ground immediately afterwards presents a black appearance. A red hue due to the soil appears as the charred debris and ashes are blown away and this is soon followed by a distinct green tint as the grass sprouts once more. At this season the hillsides might often be considered as bare and rocky, but during the rains even very rocky places become closely covered with herbage and the manner in which rainfall is absorbed may be appreciated. There may be considerable temptation to burn the grass, especially when survey lines have to be cleared, but this should be avoided, as the stranger may not know what areas of thatching grass might be involved. Moreover, the longer the grass remains the more completely it dries, so that no stubble is left when it is fired. The firing should be left to the people, who seem to do it fairly systematically. Only certain kinds of trees can withstand the annual burning of the grass around them and this no doubt accounts for the comparative absence of wood. In March and April, after most of the grass is burnt, the trees begin to show fresh foliage and many of them flower, notably the Am. *dogma* trees near the lake shores and the Erythrinas, Am. *kwara*. The latter brighten the landscape with masses of brilliant scarlet flowers during April and May. Such is the march of vegetation on the Abyssinian landscape. Under cover, during the rains, in tents, on soil with saturation level less than a metre below the surface, the rampant growth of mildew is rather trying to those habituated to the dry climates of the Sudan and Egypt.

A number of specimens and seeds were sent to Kew and our thanks are due to Dr. A. W. Hill and his staff for many identifications and also for the kindly interest shown. A collection of grasses was found to include the following:—

Acroceras oryzoides, Stapf
Andropogon polyatherus, Hochst.
Arthraxon quartinianus, Kash.
Aristida adscencionis, L.
Brachiaria brizantha, Stapf
„ distichophylla, Stapf
Chloris abyssinica, Hochst.
Chloris pycnothrix, L.
Cymbopogon, *cf.* C. excavatus, Stapf
Digitaria minutiflora, Stapf
Echinochloa pyramidalis, Hitchc and Chase
„ stagnina, Beauv.
Elusine floccifolia, Hochst.
Eragrostis gangetica, Roxb.
„ sp. near plana, Nees
„ sp.

Exotheca abyssinica, Anderss.
Hyparrhenia arrhenobasis, Stapf
„ filipendula, var. pilosa.
„ pseudo-cymbaria, Stapf
Leersia hexandra, Sw.
Panicum hochstetteri, Steud.
Pennisetum, near P. schimperi.
Pennisetum unisetum, Benth.
Sacciolepis interrupta, Stapf
Setaria atrata, Hack.
„ aurea, A. Br.
„ glauca, Beauv.
Sporobolus indicus, R. Br.

Dr. Stapf remarks that the *Echinochloa pyramidalis* and *stagnina* are among the chief constituents of the great water meadows of the inundation region of the Niger and Lake Chad, also entering largely into the *Sadd* of the Nile. On the Upper Niger they are regarded as excellent fodder grasses. He also noted *Leersia hexandra* as another semi-aquatic grass, common in the tropics.

Bamboos do not seem to grow on the greater part of the Abyssinian plateau, but there appear to be two varieties. One of these grows on the lowlands, ranging from 500 metres to 1,500 metres in altitude, and was found between the foot of the escarpment, west of the lake, and Roseires, while the other grows at a height of about 3,000 metres and was met with along the divide at the southern edge of the Little Abbai catchment between Sakala and Injabara. None was seen at altitudes between 1,500 metres and 3,000 metres. This destruction of bamboos on the lowlands west of Lake Tana is dealt with in the description of that part of the country.

Some of the trees have already been mentioned with reference to timber. The following local names in common use were noticed :—

Salein, a small palm, *Phœnix reclinata*, common near the outlet and ranging up to altitudes of about 2,500 metres.

Gambello, a small, tree Gardenia, common below 2,000 metres.

Gumarro, a species of Capparidaceæ with clusters of scarlet fruit on a thorny bush.

Kulkwal, the large, candelabra-like Euphorbia, is particularly abundant near the rocky shores around the outlet of the lake. The milky juice is regarded as poisonous and is said to destroy the sight if a drop splashes into the eye. Many had to be cut down in the course of clearing and considerable caution was exercised by the men in attacking them.

Girrar is a common flat-topped Acacia with papery bark that peels off small trees and the thinner branches of larger ones. It is very common at many places near the outlet, but the wood is regarded as useless except for fuel. It rapidly becomes bored by insects. The tree yields a gum, but this has not hitherto been collected commercially.

Kuntataffa, a leguminous thorny shrub. The spikes of winged, one-seeded pods turn brilliant scarlet and make a striking show between November and January. This and the *gumarro*, by reason of thorns, were among the most formidable constituents of the scrub near the cataracts as regards clearing.

Bamba is applied to a kind of Ficus smaller in stature but with denser foliage than that known as *Warka.*

Inkwoi, Ximenia americana, a small tree with edible yellow fruit about the size of small plums and with single large seeds.

Isha, Mimusops kummel (?) a large tree with one-seeded yellow fruit.

Maba abyssinica, Ar. *gughan,* grows to a fair sized tree near the lake and yields welcome fruit.

In early August, scarlet Gloriosa lilies are striking among the vegetation at the outlet. The Abyssinian nettle grows to heights of over 2 metres and with leaves 30 centimetres in diameter is often met with under the shade of trees in groups that should be avoided. The Carissa with its sweet-scented flowers followed by bilberry-like fruit, ripe in July, is abundant on the Abyssinian plateau up to altitudes of about 2,500 metres. Wild roses are quite common on the higher parts of the plateau and Clematis, Cotyledon, and Plumbago occur around the lake. It may be gathered that there is considerable variation in the type of vegetation according to height. The little, tree Gardenia seems characteristic of levels just below 2,000 metres. Immediately above that level, Protea, Am. *gagwedi,* occurs. From 2,500 metres to 3,500 metres or even higher, various kinds of Impatiens in many different colours are frequent. Wild olives thrive throughout a similar range and the higher parts are characterized by juniper forest with tree heaths. Bracken and maiden-hair fern grow in fair abundance at these higher altitudes, while Asplenium grows on the shores of Lake Tana. There appears to be an abundance of orchids both on trees and on the ground at all levels on the Abyssinian plateau. Polystachya and Eulophia occur near the lake.

Fauna.

Molluscs.

The paucity of shells in the lake is remarkable and for a long time during the flood they appeared to be absent. It was only when water levels fell during the dry season that they began to be seen near the outlet. At the lowest levels a number of oysters, Estheria, may be found along the rocky shores and on the bed of the Blue Nile, but they are very scarce compared with the dense growths of these shells occurring in some parts of the lower reaches. Gastropods doubtless occur among the weed on the floor of the lake, but except for an occasional Planorbis do not appear on the rocks. The shells of *Melania tuberculata, Ampularia* and *Corbicula* were observed on sandy beaches on other parts of the lake.

Insects and Crustacea.

The noxious insects, mosquitoes, ticks and other parasites have already been referred to in connexion with health in Appendix I, where several identifications have been given. At Bahrdar Giorgis in August 1920, there was a certain number of mosquitoes, among which anophelines were conspicuous as forming a marked proportion. The number increased, especially the Culex types, and the plague of these insects reached its height in November, after which it gradually declined as the dry season progressed. The pro-

tection of a mosquito net was always necessary at nights. Fleas were at their worst in April and May and the traveller should possess plenty of Keating's powder. Termites exist but never seemed to cause any damage at the camp. Ants became conspicuous towards the end of the dry season in April and May, but seemed to visit the tents chiefly in search of water and were not otherwise troublesome. Swarms of flying ants appeared in May at the time of the early rains. The destructive "woolly bears," which Mr. H. H. King informs us are the larvæ of the Dermestideæ group of beetles common in the Sudan, do not seem to exist in Abyssinia. Scorpions are rare on the Abyssinian plateau but were found at lower levels on the route to Roseires. Crabs exist on the shores of the lake and judging from castings they seem to form a considerable part of the diet of certain birds.

Fish.

A good deal of fish is obtained from the lake and river and the people use both cast nets and rod and line. At times great quantities of fish from 12 to 20 centimetres long pass up the cataracts. The runs are said to occur at intervals of fifteen days, but they are actually more frequent and there seems no reason why they should occur on one day and not on another. When the fish are running they are so abundant that they may be fairly easily caught with the hand among the rocks of the cataracts. The cataracts are favourite places for fishing, as large fish seem to lie downstream in wait for small fish damaged in the cataracts, to be carried down to them. The line is therefore baited with a small fish and dropped in at the foot of the cataract. Most of the kinds caught seem to belong to a family with quantities of bones and the flesh is almost uneatable on account of the number it contains. The following kinds are among the fish distinguished :—

Nach chassa, a golden yellow and grey fish with large scales, abundant, and attaining lengths up to nearly a metre.

Beizo, grey, also has large scales and attains lengths up to 14 inches.

Carrasso, a small fish, also with many bones.

Ambaza, the mud fish and regarded with favour, as it has few bones.

From rough descriptions, Mr. C. T. Regan, of the British Museum, Natural History, suggests that the first three of these are barbels, Barbus, while the mud fish seems to be a Clarias.

Reptiles.

A few snakes were seen. There are large warrana lizards at the cataracts at the outlet. All travellers have remarked on the absence of crocodiles in Lake Tana and nothing was seen to disprove the truth of this assertion. A small crocodile used to lie out on rocks just below Kamforo ferry, and there seemed to be only one individual, as it was always alone, near the same spot and about the same size.

Birds.

A great deal might be written about the birds around Lake Tana. Demoiselle cranes are among the most conspicuous migrants, but they do not seem to rest near the lake. In early October 1920, when they began to be seen coming southwards, they were regarded as the heralds of the cold weather; they returned northwards between February 15 and March 15, 1921. These birds were rarely seen in the daytime, but their raucous cries could be heard as they passed overhead during the evening and early part of the night. The piping of a dark-capped plover was a sound characteristic of the night almost throughout the year. Hornbills strolling in pairs were frequently met with and are regarded with superstition by the people, who say that they are harbingers of good fortune when passed on the right hand. Plantain-eaters, *Schizorhis Zonura* (?), are fairly abundant in trees near the outlet and make the neighbourhood ring with their laughter-like noise. The lesser egrets in attendance on herds of cattle are pretty sights and their value in keeping the beasts free of ticks and insects is appreciated by the people. The villainous-looking, red-beaked and red-clawed rhino birds, also found with cattle and especially on pack animals, seem only to do harm by opening sores and making them worse, though they are said to attack ticks and flies.

Game birds are represented by guinea fowl, francolin, pigeons, quail, snipe and several kinds of geese. Spur-winged geese are most abundant near the lake in the dry season, especially in March and April, when they seem to go inland to feed and return to roost near the lake. During the rains they leave the lake and remain near small streams. The cataracts are favourite resorts for all kinds of birds feeding on fish. There, are seen pelicans, grey cranes, open-billed and saddle-billed storks, darters, cormorants and diving birds of several different kinds, while grey kingfishers are often poised in the air. There were also ibis and hammer-headed storks.

Around the camp, kites were continually on watch for the smallest morsel, while vultures, big Roman-nosed ravens, *Corvus crassirostris*, as well as the white breasted Sudan crows, *C. scapulatus*, were often seen. A pair of crowned cranes used to venture as close as the dogs permitted, in search of grain left by the mules.

Mammals.

A small, black kind of rat was rather destructive in the camp. Moles occur and make molehills among the grass, but none were ever captured. The shrill cries of foxes or jackals were often heard at night. There are a certain number of small gazelle, probably oribi or duiker, but they are very wild and evidently much hunted. Leopards frequently attack the herds and may kill calves. In the river and lake there were some herds of hippopotamus, which are occasionally hunted by the so-called *Weito* people. Otter skins, from beasts presumably killed in the neighbourhood, were occasionally offered for sale. In the course of all the journeys in Abyssinia, arising from the Tana Mission, very little was seen of the larger game that might be attractive to the sportsman.

APPENDIX III.—ROUTES.

Except between Bahrdar Giorgis and Roseires, the distances along the routes have been estimated by time. Four kilometres an hour has been allowed when traversing ordinary undulating country by fair tracks and about three kilometres an hour where the paths were steep and rough. It happens that some routes have been traversed twice and the results prove to be in fair agreement. The actual distances, given in both miles and kilometres, may not be correct, but they are put forward in the confident hope that they will be found consistent and reliable guides. The altitudes are based on aneroid observations in the manner detailed in Chapter II.

The question of supplies along the routes has hardly been referred to at all in what follows. It may, however, be generally assumed that supplies of most of the ordinary produce are available when travelling among the villages of the Abyssinian plateau. These have been detailed in Appendix I and are again referred to in Appendix IV. The only routes traversed where supplies offered any difficulty were through the uninhabited areas between the plateau and the Sudan boundary towards Roseires. These only involve carrying supplies for two or three days until the next group of villages is reached. The game even in these uninhabited parts is extremely wild and the traveller would not be wise to rely on shooting for the pot.

Jibouti to Addis Abbaba.

Jibouti is the port of French Somaliland, French lines of steamers call, and there is regular communication to Aden. Steamers cannot approach nearer than about half a kilometre to the head of a masonry causeway which runs out to sea. Coral reefs secure a calm anchorage. The Governor's residence is situated on the shore at the end of the causeway. The customs house is on the opposite side of the causeway, but no duties are exacted on goods in transit to Abyssinia. Particular care is taken in regard to firearms and travellers proceeding to Abyssinia must be provided with permits from the Legation at Addis Abbaba to enable the weapons to be passed. The town centres on a square at the east end of which is the Hôtel de Ville. Around it is the European quarter with good buildings. The Banque d'Indo-Chine is represented. There are good shops and two fair hotels, the Continental and the Hôtel des Arcades.

French is the official language and the Somalis speak Arabic. The currency is francs and both Banque de France and local notes circulate. The water supply is obtained from springs to the south-west of the town. On the shore south-west of the town are extensive works where salt is prepared by evaporating sea water. The mounds of white salt are very conspicuous objects in the view of Jibouti from the sea. The town is built on low ground, probably nearly all formed of recently raised coral reefs, and the land slopes gently up towards the south. To the north, connected by a spit, is a peninsula with the terminus of the railway, the hospital, and a number of private houses. There are small mangrove swamps on the shores. The climate of Jibouti in May is very hot and oppressive.

The railway line is metre gauge and stone metalled most of the way. Trains for Addis Abbaba leave twice a week and include a composite first and second class coach, a couple of third class coaches and several vans. There are no sleeping or restaurant cars and the trip is accomplished in stages. Leaving Jibouti at about 6 a.m., Abyssinia is entered 52 kilometres from Jibouti where the line crosses a ravine, and the luncheon station is reached at Kilo. 145; but as it had been temporarily closed it was necessary to come supplied with provisions for this part of the journey. After leaving Jibouti the line rises up slopes of recent volcanic materials, generally basaltic, and cones appear in the distance. This continues to near Kilo. 90, where sandstones are met with and are traversed to near Kilo. 130. The country beyond this includes some extensive plains which appear to be underlain by basalt lavas. The surface is formed of soil sometimes strewn with boulders. The vegetation is scanty and there can only be a small amount of rain. Dirre Dawa, 1,200 metres above sea-level, was reached at about 5 p.m. Here there is the Abyssinian customs, and the railway has fairly extensive sidings. Owing to the tobacco monopoly in Abyssinia, tobacco is an item of which the import is restricted. All the luggage has to be removed from the train and must be re-registered after passing the customs. The night is spent at the hotel provided for the purpose and situated conveniently for the station. The journey is resumed and the train leaves at about 7 a.m. on the following day. South of Dirre Dawa there is an escarpment rising about 1,000 metres above the level of the line, and this feature runs parallel until the Hawash valley is reached. The lower part of the escarpment is seen along the railway west of Dirre Dawa to be formed of limestone with marly partings. Near Dirre Dawa the series dips south steeply and south-east farther west. Twenty-eight kilometres west of Dirre Dawa, basalts are met with and the line traverses country underlain by rocks of this nature until Hawash is reached. A halt for lunch is made at a station about midday and a regular *déjeuner* is served at a little restaurant. At Kilo. 206 the first view of the Hawash valley is obtained and the train runs down to the bridge across the ravine where the river flows. The station, Kilo. 240, with the hotel where the second night is spent, is reached at about 5 p.m. and is situated beside the Hawash ravine. There is telephonic communication from here to Addis Abbaba. The name of this place would be more correctly written " Auwash " and the French write it " Aouache." There is actually no " h " sound in the name. There is a change of about 20 minutes from Somali to Abyssinian time. Starting again at about 7 a.m. next morning, the railway crosses a region of recent volcanic rocks with fresh lava flows and cones until Kilo. 330 where older bedded basalts appear to be reached. The railway passes close to some lakes in the Hawash valley. After leaving the valley the train climbs a long slope. The restaurant station is at Kilo. 405 and Addis Abbaba is reached at Kilo. 480 at about 4 o'clock in the afternoon. The station is on low ground west of the Gibbi hill and about 1½ kilometres south-west of the centre of the town, where the Imperial Hotel is situated. The total length of the line from Jibouti to Addis Abbaba is 790 kilometres and water supplies are available at nearly all the stations. Section 6 includes the railway line. The heights of Dirre Dawa, Hawash, and Addis Abbaba are derived from the railway surveys and the altitudes of the other stations are from aneroid observations.

Addis Abbaba through Debra Markos, Sakala and Injabara to Bahrdar Giorgis.

ROUTE REPORT.

(June and July 1920.)

Kilometres.	Miles.	
0·0	0	Addis Abbaba. The Addis Allem road was followed to near Rufail Church. This road has been well engineered and partly macadamed. It is used by a few traction engines bringing in timber from Addis Allem. In order to avoid hills it is rather circuitous and winds through eucalyptus plantations on the west side of the town.
3·2	2	Just west of Rufail Church, which is on the south side of the road, a track branches to the left following a short cut, which saves a considerable distance.
6·4	4	Gefersa, altitude 2,600 metres, is where the track meets the main road once more. Managasha, a conspicuous dome-shaped hill stands close by to the south. A small stream winds southwards across a flat plain, sometimes marshy, and there were geese and teal.
17·7	11	Path passes 6 kilometres north of Holeta, a former residence of Menelik. The track trends slightly north of west and descends the scarp of basalt which forms a conspicuous feature in the view from the west with Managasha and Wachecha towards the south.
22·5	14	Track joins main road and telegraph line trending north-west, but farther on turns slightly north of west and pursues this direction.
28·2	17½	Berga, altitude 2,560 metres. There are many ferns alongside streams, and orchids on trees. The rocks are basalts. Path rises steadily.
32·2	20	The top of a ridge was reached from which Addis Allem appears to be 8 kilometres distant towards the south. There were fine views southwards over extensive plains south-west of Addis Allem. The path continues in a direction generally slightly north of west over more undulating country.
40·2	25	Valley floor 2,680 metres above sea level. Path continues over rise at an altitude of 2,830 metres in a direction generally slightly north of west.
49·9	31	Path turns west-north-west over a ridge, altitude 2,985 metres, formed of tuffs and basalts without apparent structure. The country is hilly and fully cultivated, with farmsteads consisting of small groups of houses but no villages. From this the path descends to a long closed valley with a wide marshy floor.

Kilometres.	Miles.	
52·3	32½	Path goes north-west along west side of valley to where it contains a small lakelet and then passes over into another valley along which is the telephone line.
58·0	36	The altitude of the floor of valley is 2,710 metres. From here the path is north-west along a narrow valley.
64·4	40	Waranbulch altitude 2,690 metres. On the road there were lilies, balsams, heaths, and hypericums. Path rises on to an undulating plateau at 2,910 metres altitude, and from here the stream at Waranbulch was seen to run north in a narrow valley with cliffs forming its sides and showing the horizontally bedded structure of the volcanics.
72·4	45	Dalgu telephone station. The track continues in a north-west direction. There are tremendous vistas of spurs falling northwards. The tops of the spurs are flat, bearing houses and cultivation.
81·3	50½	Fine view to north-west over broken country with valleys falling towards the Blue Nile and a distant plateau appears beyond. From this point there is a steep descent to 2,660 metres on a plain below. Near the top of the descent is a bed of fine grained sandstone or tuff about 40 metres thick. This is interstratified between basalts in the horizontally bedded series which is well seen from the plain below.
86·9	54	Abeibi, altitude 2,560 metres, on a plain forming the flat top of a spur. Most of the country passed over from Waranbulch to this point is covered with red basaltic soil and is fully cultivated. During the rains, the main road appears to be almost entirely ploughed up, so that the traveller continually has to turn aside to go round fields which have been cultivated right across the established track. The trees in this district bear orchids and moss and there is often moss on the telephone poles. Proceeded north-west along top of ridge to—
92·1	57¼	A point where there are fine views. The track dips down and follows ridge separating two valleys and affording a passage to the Gindabaret plateau to the north, which stands at the same level as the plateau to the south. This pass, known as Urgan, was said to be infested with bandits who attack parties crossing. There is a steep descent to—
99·4	61¾	The lowest part of the connecting ridge at 2,000 metres altitude and the path is flanked by thick woods, which would enable bandits to surprise small parties of travellers. These often wait at the top until they can join some larger party. The path ascends again and the edge of the Gindabaret plateau is reached.
107·1	66½	Customs post on edge of plateau, altitude 2,420 metres.

Kilometres.	Miles.	
111·9	69½	Haro Budatina, altitude 2,550 metres. Path continues over undulating country of the Abuna district with thick red soil and well wooded with large trees sprinkled among the cultivation.
128·0	79½	Gindabaret is situated on the north side of the plateau at an altitude of 2,570 metres and from the edge there is a fine view of the Blue Nile valley. The track follows the direction of the telephone line from the point near Addis Abbaba. At intervals there are stations in charge of linesmen who have instruments for speaking along the line. These stations are in grass huts and arrangements are very primitive, with instruments nailed to a rough tree trunk against the wall. The linesman sometimes plays the following trick on unwary travellers. He comes up and announces that someone from Addis Abbaba has been asking for the traveller, and on hearing this he accompanies the man to the hut, wondering who has wanted to speak to him, etc. The linesman rings up and calls into the instrument and perhaps actually communicates with the next linesman. Eventually he announces that it is hopeless to get through to Addis Abbaba and offers to send a message later. Whether the traveller accepts this offer or not, the chances are that he remunerates the telephone man for the trouble he has taken without suspecting that the whole affair is a hoax. The telephone line appeared to be in thoroughly bad condition and it was very unlikely that there could be through communication between Addis Abbaba and Debra Markos. The track goes north-west or north-north-west along the undulating top of the ridge.
144·0	89½	Slight descent to a lower level on the spur.
147·2	91½	Path goes over edge of plateau, altitude 2,510 metres, and the main descent begins.
152·8	95	Ereisa Sardo at a spot at 1,950 metres' altitude and about 7 or 8 kilometres east of the Gudr valley. The descent continues along a steep and bad track.
160·1	99½	At a small plateau, two-thirds of the way down, a customs post calls on travellers to halt at a large Ficus tree (Am. *warka*, Ar. *gemeiza*) for inspection of passes. The descent is very trying for loaded animals and many travellers rest them by camping here. In some parts, the track has been worn so as to have become a narrow gully along which baggage mules can only pass if the packs are loaded right above the backs in Abyssinian fashion.
168·1	104½	Ford across Blue Nile, altitude 980 metres. The stream was about 139 metres wide and the current mainly confined to a channel just under a metre deep. The current was strong and it seemed as if the stream

Kilometres.	Miles.	
		would not be fordable by loaded mules if it were 15 centimetres deeper. A chief at Debra Markos stated that the Blue Nile has been late in rising this year and this seemed to be the general opinion held by people. If this is the case, it cannot be safe to rely on its being fordable after the beginning of June. There is said to be a wire rope stretched across the river near this place, and that in flood people can pull themselves across on inflated skins by its means. A party which must have crossed the river about January 20, 1921, reported that the river was then too high to ford and that loads had to be taken across on skins while the mules swam. It appears that the Blue Nile can only be forded during quite a short period in ordinary years. Probably from the beginning of March until the middle of June. The flood channel is about 280 metres wide. The ford is known as Malka Kailo and the north bank is known as Liban. The district name appears to be Kutai and this is the name usually given to the route. There are alluvial shelves flanking the course of the stream and a good camp site, altitude 990 metres, was found at the foot of the track on the northern side of the valley, about 300 metres downstream of the actual ford. The muleteers usually prefer not to stop at the river but to camp some distance above it. The track rises steeply in a direction slightly east of north and with the exception of some small shelves due to the outcrop of harder beds of sandstone there is a steep climb almost all the way up to the customs post under a large *gemeiza* tree—
182·2	113¼	At Gimam, altitude 1,850 metres. There is a welcome spring of water close to the *gemeiza* tree. The telephone line in the valley lies some distance to the west of the track and at Gimam it is met with again. Stretching south-west from the *gemeiza* tree is a flat topped spur known as Zami, bearing houses and cultivated land.
185·4	115¼	Top of basalt escarpment, altitude 2,100 metres. The path goes northwards along the east side of a spur, altitude 2,230 metres, and there are splendid views of the Blue Nile valley towards the east. The Muger river and the Mitar, a small tributary, could both be seen discharging small quantities of muddy water. This was particularly distinct at the mouth of the Muger river, where the Nile was green above and brown below. At the mouth of the Muger river the Nile valley is wide and contains fairly extensive plateaux at low levels. It appears to afford a possible route for a railway to connect Gojam with Shoa.
199·1	123¾	Degat Mariam, altitude 2,210 metres. Path ascends east of north over rotten basalt and red soil to—
204·0	126¾	Top of scarp, altitude 2,380 metres, path turns to north-west on plain which slopes gently northwards with wide-floored, grass covered valleys and cultivated slopes. Path afterwards turns north to—

Kilometres.	Miles.	
216·0	134¼	Near Yaush, altitude 2,280 metres. Path continues north-west and—
222·9	138½	Crosses valley about 4 kilometres wide.
226·1	140½	Path skirts the edge of the plateau above the Chamoga valley into which there are fine views. The existing maps give no idea of the topography of this district with its sharply defined deep valleys cutting into the plateau, where the streams traverse gently undulating country.
232·9	144¾	Chamoga stream crossed just above edge of plateau where it was 16 metres wide and about 40 centimetres deep. It was turbid with rain water but was said to carry nearly as much during the dry season, while it is unfordable during the rains. The road continues north of west.
236·2	146¾	Debra Markos, altitude 2,420 metres, Ras Hailu's Gibbi is situated on a ridge running north-east to south-west and about 100 metres above the surrounding country, with a large church just to the south. On the lower part of the ridge to the north is a collection of huts, but there is nothing that can be regarded as a town. The whole of Debra Markos would compare with a large village in the Sudan containing perhaps about 5,000 people. The market is held on Saturdays and large numbers of people attend. Water is drawn from a small stream on the south-east side of the ridge.
241·0	149¾	About 3 kilometres from Debra Markos the path skirts some plantations belonging to Ras Hailu, who has constructed an aqueduct fed by a dam on a small stream. The path descends over the Wonka slopes, of tuff giving rise to loose sand, to the floor of a wide valley.
243·8	151½	Stream at the south-west edge of marshes, which are muddy and bad going both in June and December.
244·2	151¾	Stream running south-west and forming the limit of the marshes. The path then rises to the top of a ridge which is formed of a bed of grey tuff with fine grained sediments and doubtless corresponds to the bed on the Wonka Hills. North-west of this several small streams with rocky beds are crossed.
256·3	159¼	The path fords the river Gyedev, big and swollen, discharging about 3 cubic metres a second in June; 20 metres wide and 30 centimetres deep in November.
258·7	160¾	Yeula, altitude 2,260 metres, is to the west of Sassi.
263·5	163¾	Ras Hailu's rest house on a ridge at Amanwel.

Kilometres.	Miles.	
266·7	165¾	River Timdauat, altitude 2,420 metres, in the district of Dilmar Amanwel. The path continues over rather hilly country with red soil and grassy slopes but little cultivation.
270·4	168	High ridge with views of Amedamit to north-north-west and other peaks to the west, perhaps including Adsum Sillasi. To the south-west the plateau is cut by deep valleys and through a gap can be seen distant hills, probably on the south side of the Blue Nile valley.
270·8	168¼	Small stream, altitude 2,390 metres, path proceeds north-west.
275·6	171¼	River Temtcha; at the end of June this was about 1 metre deep and was discharging about 7 cubic metres a second. In November it was 10 metres wide and about 35 centimetres deep. It is situated in a steep-sided valley about 50 metres deep, cut in basalt. It must rapidly feel the effects of rain. The path here proceeds in a west-north-west direction.
278·8	173¼	Gwudila river, altitude 2,070 metres, about 800 metres south-east of Dembetcha. In November it was 30 centimetres deep and 15 metres wide.
279·6	173¾	Dembetcha is situated on the south-east face of a ridge running south-west just below a higher hill to the north-east. Ras Hailu has a residence here. The telephone line runs to this point and on the east side of the village there is a customs post where passes are demanded. Some important chiefs reside here. The route passes through the town along paths between hedges surrounding cultivated plots on which the houses stand. The hedges, like those of Addis Abbaba and elsewhere in Abyssinia, are of Justicia. Even at the end of June at an early stage of the rains the bouldery paths were deep in mud. They were in a similar condition in December.
281·2	174¾	The Bure path continues west-north-west, descends from the ridge and enters forest. The trees are covered with orchids.
288·9	179½	Open cultivated country begins beyond Cheraka, a small stream discharging about one cubic metre a second in December. The track continues over red soil, altitude 2,040 metres, and further on, decomposed basalt is exposed on a descent. At the foot of this is—
292·0	181½	A valley containing a floor of dark soil, shown by cuts to be more than a metre deep, but on the slopes is the normal red soil.
292·8	182	Kajam river, altitude 1,790 metres, about 40 centimetres deep and the level had clearly fallen since the previous day, at the beginning of July. It was 6 metres wide and 20 centimetres deep with a discharge of about 1 cubic metre a second in December.

Kilometres.	Miles.	
294·4	183	River Birr, flowing south-west with 120 centimetres depth of water at the ford. There was a rickety bridge made by throwing a couple of trunks across a rather narrow place where the river flows in a deep gully, but this had not been repaired lately. At the highest stage, water seems to rise about 1 metre higher. In December it was discharging about 2 cubic metres a second, the bridge had been repaired and the path to the ford was obliterated by herbage. The altitude of the bank at the ford is 1,790 metres.
		Taking the Bure road in a west-north-west direction from the ford—
295·2	183½	Path branches off to the north-west, passing west of Jigga, where Ras Hailu has a rest house on a small hill.
300·1	186½	Turns north towards Amdasha and traverses almost level plain with a good deal of cultivation to near—
304·9	189½	Den Kadami market place, which is situated on a ridge, altitude 1,990 metres. Here a path branches off to the right over the Amedamit Mountains. In December much of the country from the Cheraka river up to this point was covered with grass often over 2 metres high. North of the ridge is more cultivation, which terminates against steep hills about 5 kilometres to the north. The path follows a valley to the north-west.
316·2	196½	Asawa Mariam, altitude 1,850 metres, 2 kilometres south-east of Gabesi Mikail on the side of a valley about 2 kilometres wide with cultivation on the lower parts of the slopes. Path continues up the Mikail valley until it rises on the west side with fine views towards the upper part and then—
320·2	199	Crosses over a col, altitude 2,330 metres, to Asawa Madahni Alam and continues to the west across the valley.
330·7	205½	Crosses col, altitude 2,390 metres, into another valley where the path descends and goes north-west.
331·5	206	Shelf at altitude 2,340 metres, below col above a marshy valley.
335·5	208½	The path traverses almost level ground and Guderabar lake is reached and lies to the north-east of the track, which crosses marshes to the west of it. There appears to be no outlet to this lake. North of it the path rises to—
346·8	215½	A divide, altitude 2,720 metres.
347·6	216	Sakala, at source of Abbai 2,710 metres above sea level. The Church of SS. Mikail and Zarabruk, the patron saints, is situated on a ridge about 250 metres north-east of the sacred spring. The track goes west, parallel to the Abbai valley on the north, passing the head waters of

Kilometres.	Miles.	
		several small streams. There are extensive views northwards over the rolling plains of the wide Abbai valley. Along the track the country is undulating, with cultivation on the lower slopes.
366·2	227½	Wooded, park-like country, altitude 2,490 metres. Path trends westwards.
371·0	230½	Steep ascent and the track was difficult towards the top, where there is—
371·8	231	A plateau standing at about 2,790 metres above sea level. There is cultivation on the plateau and several peaks rise above it. The most prominent of these is Adsum Sillasi with a rounded cap formed of a columnar volcanic sheet. (Ligga is west of the Abbai source. Wombetta is another name for the Gish Mountain at Sakala). The track continues west along the edge of the catchment with views of the Abbai plains to the north. These appear to be very flat and lie perhaps 300 metres below the level of the track. Rising ground is seen to bound them both on the east and on the west for a distance of at least 30 kilometres to the north. Path continues to—
385·5	239½	Injabara, altitude of camp 2,570 metres (aneroid), 2,610 metres (boiling point). Ras Hailu's Gibbi is on a hill about a kilometre south of the camp and at about 120 metres higher level. It is on the watershed and commands views southwards over valleys draining towards the Blue Nile.

INJABARA—DANGILA.

0·0	0	Track from Injabara goes northwards and falls over fairly steep slopes. There are exposures of basalt.
6·4	4	The foot of the slopes is reached and the track continues over gently rolling plains. In places near the tops of ridges there are marshy pools.
15·3	9½	Kwakwera, at an altitude of 2,320 metres above sea level. Here there is a waterfall with a drop of about 10 metres over the edge of a sheet of basalt. The altitude of the camp, about 1·5 kilometres north, was 2,280 metres. The track continues northwards over gently undulating plains with swampy hollows.
25·8	16	Camped on low ground, altitude 2,130 metres, and about 400 metres south-west of Dangila. There is another village about a kilometre to the north. Dangila market is on Mondays.

Injabara to Bahrdar Giorgis.

Kilometres.	Miles.	
		Followed the track eastwards in the direction of Sakala. To begin with it lay just to the south of that by which we arrived and later the two joined.
399·2	248	Camped north of Adsum Sillasi at an altitude of 2,630 metres above sea level. Route separates from the Sakala path but makes a similar descent.
402·4	250	Altitude near top of descent 2,530 metres.
403·2	250½	Foot of descent, altitude 2,440 metres. Up to this point the path trends east, but here, from approximately opposite the point of the former ascent, it turns north-east and diverges from that to Sakala.
406·5	252½	Large stream marking boundary between Agaumidir and Meicha.
414·5	257½	Altitude 2,230 metres just west of the Abbai in the district of Bifetta, which lies to the north-east of Fagetta.
415·3	258	The Abbai proved already to be a powerful stream in a deep channel about 7 metres wide, discharging at this season, towards the end of July, perhaps about fifteen cubic metres a second. It was crossed by a temporary bridge.
416·9	259	Gwodar river crossed and from this the path rises in a north-west
420·9	261½	direction through dense forest. When the path emerges from the forest, extensive undulating country is seen to the north. The north-west trend of the path was evidently taken to avoid a steep ridge.
428·1	266	Gutta at 2,100 metres above sea level. Track continues north-east over gently undulating country to—
433·0	269	Waramat river about 1 × ·15 metres.
434·6	270	Jamma river. Between these two rivers there is an almost flat plain with slight slopes to both streams, but it was too water-logged to cultivate. The Jamma river was 20 metres wide and 1·5 deep, with a surface velocity of about a metre a second, and it was discharging about 18 cubic metres a second. When it is full to the top of its banks it must carry about 50 cubic metres a second. It is obviously subject to floods and high discharges would not be long maintained. At this point where the Jamma leaves the hills it flows in a wide alluvial plain of its own formation and probably the whole of the plain between it and the Waramat is also alluvium of a deltaic type. East of the Jamma is the Samsi Rock, a northern outpost of the Amedamit Mountains.

Kilometres.	Miles.	
435·4	270½	Buretaffa, at altitude 2,050 metres, on a rise of about 15 metres above the bank of the Jamma river. The track goes north-east over slightly undulating country of red soil.
436·2	271	Small stream.
445·1	276½	Small stream.
445·9	277	Rim, at 2,080 metres above sea-level.
446·3	277½	The Kwoga river, 15 m.×0·5 m. The path continues over slightly undulating country.
460·6	286½	Camped at altitude 2,100 metres, a little way west of Debra Mai. Path continues over undulating country with red soil. The valleys are swampy and the slopes either cultivated or grassy.
465·1	289	Altitude 2,160 metres on plateau near Debra Mai. There are many churches around. Proceeded north by a circuitous track to avoid streams.
472·3	293½	View of Lake Tana. There is a very distinct volcanic cone, Mikara, about 1·5 kilometres distant to the north-west from this point.
475·5	295½	Passed east of the volcanic cone, then turning north-west skirted its north slopes. To the east, beyond broken country, is the great valley containing the Blue Nile. There is a steep descent from altitude 2,110 metres to—
482·8	300	Plains below at an altitude of 1,960 metres. and these are traversed by—
485·2	301½	The River Andassam, altitude 1,850 metres. The water had fallen about 70 centimetres before midday on July 28. It was then about 20×1·2 metres with a mean velocity of about 0·5 metres a second. At this point the Andassam flows in what appears to be an alluvial plain with terraces flanking it. The lower one is about 4 metres above the stream bed and the upper one, about 3 metres higher, is strewn with scoriaceous basalt. Farther north the plain is seen to be formed by the surface of a sheet of basalt and this continues to the shore of Lake Tana, at—
494·1	307	Bahrdar Giorgis which is situated about 3 kilometres from the outlet.

General Description of the Country from Addis Abbaba through Debra Markos, Sakala and Injabara to Bahrdar Giorgis.

The country immediately west of Addis Abbaba as far as Hapta Giorgis springs is described in connection with the water supplies for the town. The track and main road follow the north side of a wide valley which lies between the Entoto range on the north and the Managasha and Wachecha Hills on the south; the floor of the valley is undulating and is traversed by small streams which are flanked by marshes in the rains.

From Gefersa the track trends to the west-north-west and rises on to a ridge from which there are very fine views over Addis Allem and the plains to the south-west. Here there is a juniper forest and it is said that these trees supply the bulk of the wood obtained from Addis Allem. For the first 70 kilometres to the north-west of Addis Abbaba, the track can be described as crossing gently undulating plains with often wide floored valleys separated by ridges that seldom rise more than about 60 metres above the streams. The floors of these valleys bear sedges and are marshy during the rains. Ground on the slopes is selected for cultivation. The proportion of run-off in such country must be quite small and this is borne out by the presence of a small lake without an outlet in one of the valleys. Time did not permit investigation as to what had caused the lake to form. The surface of the country is formed of red basaltic soil and there are occasional outcrops of basalt, but there is too much soil and vegetation to allow the structure of the country to be seen.

At a distance of about 70 kilometres north-west of Addis Abbaba the undulating plain becomes broken up by deep valleys falling northwards into the Blue Nile. The sides of these valleys are steep and exhibit the horizontal bedding of the basalts of which the country is built up. Near the top of the descent just to the south of Abeibi there is a bed of sandstone or tuff about 40 metres thick interstratified with the basalts. The basalts which form the surface of the plateau are not very thick in the neighbourhood of this part of the Blue Nile valley and the beds below are met with in the Urgan pass on the track about 92 kilometres from Addis Abbaba. Here there is a bed of limestone, partly dolomitic, with some local dips due to slipping. The horizontal structure of the country is displayed on the neighbouring valley sides, and the limestone, which is at least 60 metres thick, lies below the basalts. It corresponds with and is certainly a continuation of the Antalo Limestone which Blandford described and concluded to be of Jurassic age. The presence of this limestone relatively high up on the slopes of the Blue Nile valley may be of considerable importance if supplies of lime are required.

North of Urgan the path crosses Abuna on the Gindabaret plateau and here there is abundant evidence of the moist climate prevailing during a part of the year. The trees are often festooned with the " old man's beard " lichen, and bear orchids and ferns (Platycerium). The Abuna country on the plateau is very pretty with gentle undulations and red soil of considerable thickness extensively cultivated and sprinkled with many large trees, including *Sigda, Podocarpus gracilior,* a kind of yew said to yield good timber. This was the only place where these trees were seen. No rock was seen towards the northern edge.

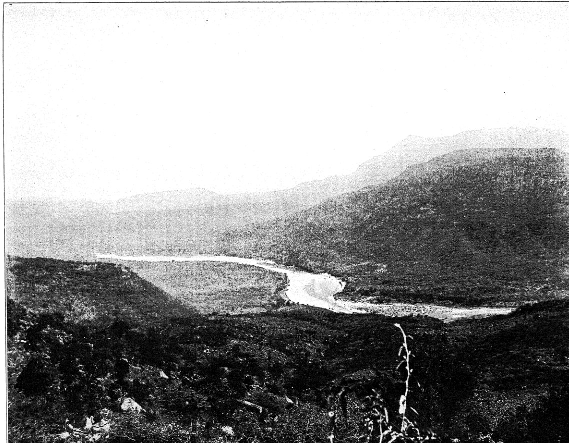
Fine views of the Blue Nile valley are obtained from the north side of the plateau. The structure with horizontal bedding is conspicuous and Gojam on the north side of the valley appears to be a plateau of about the same height. The path descends over the edge and blocks of limestone and sandstone were met with just above Ereisa Sardo. The

rocks were not well displayed on the route and the bases of the basalts and the limestone are obscured by talus and were not seen, but are certainly above the position of the camp at Ereisa Sardo. Below are exposures of the horizontally bedded sandstone in which the Nile valley is excavated. This is of considerable interest, for, looking down from the bedded basalts which form the surface of the plateau and its extensions on the tops of the spurs, the horizontally bedded rocks may easily be thought to be other basalts. Indeed, the rusty, weathered surfaces of the harder sandstone outcrops resemble the appearance of basalts. The existence of this great thickness of sandstone on the slopes flanking the river bed may have important influence as a reservoir in supplying part of the low stage flow of the river.

The path continues to descend over horizontally bedded sandstones of either fine or coarse grained character. The lower part of the valley and the winding river bed are shown in Photograph 30. There is a considerable change in climate in the course of the descent and this is shown by types of vegetation. A little way down gardenia trees are met with and form a considerable proportion of the scrub. White ant hills, which are not seen on the top of the plateau, also occur and among the trees lower down there are several kinds of combretums. At the bottom, 995 metres above sea-level, alongside the river, there are a few *Acacia arabica*, Ar. *sunt*, *Combretum ghazalense*, Ar. *habil*, *Tamarindus indicus*, Ar. *aradeib*, *Vitis quadrangularis* and plenty of the herb *Tribulus terrestris*, Ar. *dreisa* with its spiky seeds.

The Blue Nile at this point on June 22, 1920, was still quite low. There were muddy marks on the stones, showing that a flush from a rainstorm had passed down and had raised the water level temporarily. Judging from the extent to which the stones were covered with algæ the level of the water was 5 or 10 centimetres above that at which it had stood at the lowest stage. The discharge was measured with a current metre by Mr. Black and found to be 28·6 cubic metres a second. The stream was 139·5 metres wide with a maximum depth of 95 centimetres. The water was still turbid with red silt, showing that there was a proportion of flood water. The smallest discharge of the river may be about 15 per cent less than that observed. Marks on the banks show that the river can rise to about 5 metres above its low stage level and then, with a width of 285 metres, it must attain a volume of between 2,000 and 3,000 cubic metres a second, and even accepting the larger of these figures it appears that the upper part of the Blue Nile valley contributes a relatively small proportion of the volume which reaches the Sudan during the flood time.

Sandstone was traversed right to the bottom of the valley. The bed of the river is formed of boulders mostly about 15 centimetres in diameter but ranging up to 30 or even 40 centimetres, and composed principally of basalt but including a small proportion formed of limestone. The size of these boulders shows that the normal flood current must be very powerful. At the mouth of a small tributary is a fan of sandstone boulders up to nearly a metre in diameter. This rock is not resistant to attrition, it is rapidly comminuted and the resulting sand is swept away, so that hardly any trace of it remains in other parts of the river bed. There are coarse conglomeratic varieties of sandstone that yield quartz gravel and may account for the beds of this material forming the river terraces near Roseires. The valley near the ford represents a vast mass of sandstone that has been eroded and carried away and the small proportion of pebbles would account for all the older gravels of the Roseires district. In spite of the great proportion of sandstone forming the valley sides, the material of the river bed is derived almost entirely from the



No. 30.—The Blue Nile Valley at Kutai.



No. 31.—Across the Blue Nile and up the Muger Valley.

basalt, and the reason is that this is tougher and withstands attrition by powerful currents. At Roseires the older alluvium consists mainly of quartz gravel with only a small proportion of basalt, while the modern river bed is composed almost entirely of basalt shingle ; and though at the neighbourhood of the ford both materials are available, it is difficult to suggest the characters of the climatic conditions which resulted in distinct beds of the different materials.

The sandstone series contains red and grey mudstones identical with those of the Nubian Sandstone series of the Anglo-Egyptian Sudan. The outcrops of hard beds form shelves on the valley sides and several of these were met with on the northern slopes notably at 1,390 metres, 1,590 metres, and 1,820 metres above sea-level. The sandstone is exposed for a considerable distance up the tributary valleys. The limestone was not observed on the north side of the valley, where the basalt appears to rest directly on the sandstone, just below the level of the custom's post at Gimam. No evidence of the existence of limestone, such as loose fragments, was seen in this neighbourhood. The basalt capping resting on the sandstone on the north side of the valley proves to be relatively thin and, except for the absence of the limestone, agrees with conditions on the southern slopes. Bedded basalt above Gimam extends out into the valley as a capping to the Zami spur to the south-west. The path follows the top of the ridge northwards and Photograph 31 is a view towards the east, showing the junction of the Muger river with the Blue Nile. The country in the valley flanking the ridge proved to be mainly of sandstone, which just here forms the bulk of the effective Nile catchment. The top of the ridge towards the north is covered with rotten basalt and red soil. At the top of the escarpment, where the edge of the plateau is reached, there is an exposure of lateritic ironstone associated with the red soil. The surface of the plateau is undulating and much of it is cultivated, while far off towards the north the Choke Mountains appear rising above it. An extraordinary contrast is experienced in passing almost in an instant from the wild slopes of the Nile valley to the gentle aspect of the plateau above it with grass covered, wide-floored valleys with cultivated slopes, showing that the run-off from the rainfall must be quite small as compared with that from the steep slopes of the valley of the Blue Nile. The small size of the streams supports this conclusion and often there is no defined channel for the drainage of wide spaces towards the upper parts of the grassy valleys. There were rains in the afternoon and early night of June 26, but next morning the streams were not swollen. To the north-west of Yaush is a larger valley $1\frac{1}{2}$ kilometres wide with drainage lines which were found not to have flowed as a result of the rains. The stream beds were too small to carry any considerable volume and suggest that the run-off from such country is less than 10 per cent. These valleys feed small permanent streams which carry off the soil water.

On one occasion at the end of June vapour was noticed rising from a ploughed field, while there was none rising from the surrounding grass land, as if the bare soil was the warmer.

In the country west-north-west of Debra Markos beds of rhyolite tuff are intercalated among the basalts and one of these beds exposed on the Wonka Hills, about 6 kilometres from Debra Markos, is at least 10 metres thick. The microscope shows it to be composed of angular pieces of brown glass. The bed contains rounded pebbles of grey rhyolite. Some ridges between the valleys display the horizontally bedded basalts among which the sediments are included. South-east of Dembetcha there is country of red soil, but dark soil occurs in hollows. The path traverses an undulating plain which falls towards the south-west and is cut towards its edge by deep valleys. Exposed in the bed of the

River Timdauat at Dilmar Amanwel is a mass of basalt with irregular jointing, but weathering has revealed signs of its being part of a horizontal flow.

Though there had been heavy rains almost every day since June 4, really swollen streams were not met with until June 28, between Debra Markos and Dembetcha.

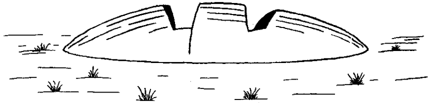
At the Temtcha there are groups of *Musa ensete*, the only examples of this plant met with wild in Abyssinia, and here the small phœnix palm was also noticed for the first time. There were quantities of different kinds of balsams with flowers ranging from white to red or purple, many wild roses, orange flowered leonotis and celastrum trees in this region. The Temtcha and several other streams running in a south-west direction through this district evidently drain from the Choke Mountains. There is a prominent ridge just west of Dembetcha. Beyond it the country falls and the lower level is shown by the presence of gardenia shrubs in the Birr valley at the place where it is crossed. The ridges west of Dembetcha are more defined, with steep slopes, and between them are wide, nearly level, grassy or forested floors, often with black soil. The plateau structure of the country is shown by horizontal benches around the ridges, and though they are grassed over they remain striking features. A bed of vesicular olivine basalt is well exposed in the bed of the Birr where it has been pot-holed and cut into, to an extraordinary extent. The surfaces of the rock have been scored and fluted by the stream in a way resembling the action of wind-driven sand and it is likely that the mechanism of both is very similar. This is a result of a rapid current which is evidently capable of transporting large boulders. Small ones up to 20 centimetres in diameter were seen on the banks above the water level at the time of crossing and in one place the chasm in the basalt has been bridged by a boulder brought down by a flood, so that when there is only a moderate amount of water the river can be crossed dryshod. In some places there was a black film on the rocks.

The country flanking the river at the ford is traversed by small drainage lines, but there had not been enough rain previous to June 30 to make them flow. The run-off that supplies the river cannot be local but must come from the mountains to the north.

To the north-west and north of the point where the Bure road fords the River Birr there are almost level plains with black soil on the flat parts and red soil on slight slopes, showing that the dark colour is due to humus. The black soil is more friable and lighter than the red and both bear much cultivation. The plains extend to near Den Kadami, where hills are reached. To the north-west of this, the path follows valleys in country with bedded basalts forming the hills.

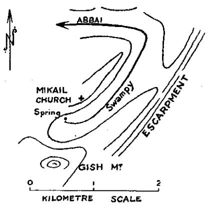
At Asawa Mariam 9 millimetres of rain were measured in the afternoon, but this fall was not enough to produce any run-off from either the grass or the cultivated land. The stream must have been filled from the slopes. A tributary stream enters the flat and crosses most of it, with marked berms, so that though the bed is below the neighbouring valley floor this cannot drain into it, with the result that there are marshes in places. The grass on other parts of the valley floor was already, July 2, about 30 centimetres high and its growth must absorb a great deal of water. On this date there was rain after sunrise and it was the first occasion on which rain had been enough to really wet the ground. The floor of the valley to the west was sodden, with water standing 5 centimetres deep among the grass and slowly draining downwards towards the stream. The water draining in this way was merely opalescent and most of the small streams were practically clear. The valley contains red soil and there are ridges of basalt with smooth slopes almost as if they had been glaciated, but the horizontal features due to bedding are still visible.

The path passes over a col on the west side of the valley and then turns north-west, skirting the south-west shore of the Guderabar lake. This is oval in shape, 3 or 4 kilometres long in a north-west to south-east direction and $1\frac{1}{2}$ or 2 kilometres wide, with marshy shores. On the east and north-east it is flanked by hill slopes, and the path traversed the south-west and west sides without meeting with any trace of an outlet, and the absence of an outlet was confirmed by statements of the people. The country to the west of the lake is formed of highly vesicular basalt which bears evidence of being a comparatively recent flow and this may explain the existence of the lake. The surface is broken by a number of hummocks and in the marsh to the north-west of the lake several of these, about 30 metres in diameter, have the appearance of large bubbles that have burst.



There are vesicular structures parallel to the surfaces and the appearance of one of these hummocks is shown in the sketch. At the north end of the lake is comparatively low country and though it was not traversed good views were obtained and no appearance of an outlet was seen. There are several small pools in the marsh the surface of which appears to be distinctly above that of the lake. There is a stream coming from the north-east running south-west across the marshes and the delta of this stream may have been a factor in the formation of the main lake. At the beginning of July it was discharging about a cubic metre a second and if it ran into the lake it would certainly fill it, but as it would run in at the lowest point in the periphery, the lake would soon be cut off by the delta. It is practically certain that the Guderabar lake has at present no outlet. It is said to rise about 1 metre during the rains and there is a line near the highest part of the ridge at about 3 metres above the July water level, which may mark an exceptional level.

The marshes continue west of the lake and a broad flat valley turns south-west and presumably subsequently drains southwards. There is a small cone-shaped hill to the north-west which appears to be volcanic and the vesicular basalt extends for a distance of about 2 kilometres north of the marsh. Beyond this to the north are slopes of basalt with red soil and these rise steeply to the shelf at Sakala, where the source of the Abbai is situated.



The striking feature of the source is its situation on a narrow shelf of high ground from the edge of which to the south-east

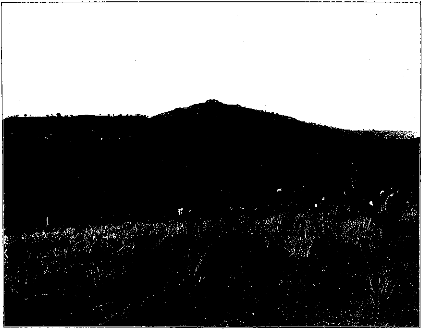
there are steep slopes down to plains about 300 metres below. This is indicated in the rough sketch annexed and, looking southwards from the slopes near the church, Photograph 32 shows the position of the spring at the foot of the Gish Mountain. In fact, within a few hundred metres of the holy spot, there are views from the edge over country draining straight into the lower part of the Blue Nile at the south of Gojam. The Gish Mountain referred to by Bruce rises immediately to the south-west of the spring. The country rock of the district is a vesicular basalt generally covered with red soil.

At the source of the Abbai there is now one principal spring about 120 centimetres in diameter, lined with wood and surrounded by a palisade of bamboos, Photograph 32. There is no flow from the spring, which is better described as a pit in a small bog, lying against the north side of the valley. It is, however, the source from which the holy water is drawn and is referred to as *tabal*, a term also applied to the holy water in churches. The water stands about 120 centimetres above the trough of the valley close by and access is obtained over logs and branches that have been thrown down on to the surface of the bog. Apart from these there is nothing firm and a stick was pushed down to a depth of 150 centimetres without meeting with any obstruction. Bubbles, probably of marsh gas, rise through the water. The surface of the bog falls away to the south-east to the bed of the valley and a stream issues and traverses some swamps before reaching a more defined channel at a distance of about 2 kilometres north-east of the source. It then turns and flows west down a fair gradient. The bog is said to be perennial and the whole situation suggests that there is some underlying source that supplies the water. There is very little higher ground above the level of the spring and it seems unlikely that there could be enough underground water from it to supply the spring. If it proves to be a source of volcanic origin like many of the hot springs of Abyssinia, its remarkable situation near the top of a steep slope would be accounted for.

The legend about the spring relates that Zarabruk, a native of Densa, prayed to God for twelve years and the spring was found as a result. King Azaracho cast him into prison and he was kept in a dungeon for a year. The jailor found a light radiating from Zarabruk and reported his sanctity to the king. Zarabruk performed another miracle by keeping his food and handing it back to the king on his release, when the bread was found hot and fresh as if it had just been baked. He returned to the spring. The book he had left was returned by the waters and people resorting to the spring have been cured ever since. In times of drought a bull is sacrificed at the spring and it is said that rain comes as soon as this is done. The church of SS. Michael and Zarabruk, about 400 metres north-east of the spring, stands on a ridge. The spring is resorted to by many Abyssinians, including chiefs of great importance, and besides offerings to the church good revenues accrue to the priests and the local chief.

The source of the Nile was sought by early travellers and it is of interest to compare their accounts with the present conditions. Pedro Paez (1) reached Sakala in April 1618 and he appears to have been the first European to see the place. His descriptions are recorded by various authors and form the basis of those given by Jeronimo Lobo, Kircher, and Ludolphus. There were then two fountains, each about four palms in diameter, and he sounded their depth with lances without meeting with solid ground. In those times,

(1) "Discoveries and Travels in Africa," Murray, Vol. II, pp. 39-41, London, 1818.



No. 32.—Holy Spring at Sakala.—The Source of the Little Abbai.

many cows were sacrificed at the spring. Bruce of Kinnaird [1] arrived at Sakala in November 1770 and, except that he records there were three springs and the marsh to have been very much larger, his description accords very well with facts as they exist to-day. Quite probably the extent of the marsh may be explained by Bruce's visit having occurred soon after the rains. Bruce in his haste to reach the spring stumbled over bulbous plants and descendants of these still grow on the slope above it. There was then a principal spring provided with an altar, where sacrifices were made.

At Sakala there were bamboos and junipers, and heaths were seen in the valley to the west. The small, brick-red balsam occurs abundantly in these valleys. The plant grows with a central stem and recumbent branches, a habit entirely different from the white and pink balsams, which are erect and attain heights up to 1 or 1·2 metres, while the red hardly exceeds half a metre. The brick-red variety has red tubers, which are conspicuous on ploughed land.

The track traversed several marshes and it seems possible that these might be drained. On July 4, a rainfall of 29 millimetres was measured. The camp was on a park-like, grassy slope and even with this heavy rain there appeared to be only a very small proportion of run-off. Farther on to the west, swampy ground near streams had become sodden and clear water was draining away.

The path rises on to a plateau from which there are extensive views northwards over the plains of the Abbai valley. These are very flat and suggest that the proportion of run-off must be small. On descending from Injabara to these plains additional evidence of a small run-off was found in the existence of marshy pools near the tops of ridges. Much of the surrounding land was cultivated and the ploughed land had absorbed all the recent rainfall.

On July 8, 8 millimetres of rainfall was measured in the early afternoon. This had the effect of completely wetting the ground and the water lay among the grass, slowly draining down the slope. The site was on gently sloping grass land that had been cultivated and was still marked by parallel ridges about 4 metres apart. The grass at this early stage of the rainy season was still small, but even so it helped to hold the water on the land and there must be very large losses on the run-off. Later on, when the grass attains heights of 2 metres or more, the losses must be larger, as there is a larger surface of grass to wet and there is a much greater transpiration drawing on the soil water.

On the slopes and in the stream beds basalt is exposed, and where the path has cut down, rotten basalt is met with beneath the soil. The soil of the plains between Injabara and Dangila is typically red and is certainly formed by the decomposition of the basalt of which the country consists. Injabara is marked by a prominent rock which rises to a height of about 100 metres. It proved to be trachytic. The Adsum Sillasi peak appears to be of similar rock and there are several other peaks of the same type in the country west of Injabara.

The hills to the south and south-east of Bifetta are partly wooded, but to the east there are some of smooth bare rock, almost suggesting glaciation. Otherwise the structure is much obscured by vegetation, but enough is visible to show that the hills are formed of bedded volcanic rocks. The rock is either trachyte or basalt.

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[1] "Bruce, Travel to Discover the Source of the Nile," Vol. III, pp. 632-640, London, 1790.

The Amedamit Mountains show features of horizontally bedded volcanic rocks. From Debra Mai the beds appear to have a slight dip down the valleys. The Jamma was crossed near where it leaves hills and it follows a very sinuous course in a wide alluvial plain of its own formation. Probably the whole plain between it and the Waramat river is also alluvium of a deltaic type. The basaltic sand would soon decay and produce red soil identical with that derived from solid rock.

Some distance to the north of Rim there is a distinct volcanic cone about 30 or 40 metres high and about 200 or 300 metres in circumference. The outlines of another hill to the north are also suggestive of a volcanic cone. In this region there are several bosses besides the Samsi Rock the outlines of which suggest either local intrusions or cores of volcanic necks. One, passed on the east side of the Kwoga river, was seen to consist of a compact blocky rock showing dyke-like jointing on the north side and it is very probably the core of a volcanic neck.

East of the Jamma the ground is slightly undulating and about 2 metres of red soil were seen to rest on the decomposed basalt in some places where the surface had been cut by recent erosion.

Towards Debra Mai the lower level of the country is shown by the presence of proteas and gardenias among the small trees.

Near the point on the track northwards from Debra Mai where a view of Lake Tana is first obtained, there is Mikara Hill, a conspicuous volcanic cone, horseshoe-shaped in plan, and the crater, about 1 kilometre across, has been breached towards the north. Fresh vesicular basalt is associated with the cone and there is evidence that a flow issued northward from the breach. This and the cone seen from Rim show that there has been recent volcanic activity in this district. This is not to be confused with the great volcanic eruptions which built up the basaltic plateau of Abyssinia. These older rocks are exposed on the sides of the Blue Nile valley, which came again into view north of Debra Mai. The beds on the south side appear to have a slight dip towards the north, as if they had been erupted from a centre near the present highest hills.

On descending the slopes to the Andassam a flat plain is reached which appears to be an alluvial flat. This is strewn with pieces of scoriaceous basalt, which suggest that the flat is the surface of a basalt sheet that forms the valley floor and extends to the shore of Lake Tana at Bahrdar Giorgis.

Bahrdar Giorgis to Dembetcha.

ROUTE REPORT.

Bahrdar Giorgis to Dembetcha *via* Agam Dildi.

(November 1920.)

Kilometres.	Miles.	
0·0	0	Started from camp, Bahrdar Giorgis, followed path to Egirrbar.
4·8	3	Path turned east and separated from direct track to Zarabruk. The hills on the side of the valley are of horizontally stratified rock. The path is over soil with outcrops of vesicular basalt.

Kilometres.	Miles.	
6·8	$4\frac{1}{4}$	From here the path trends south-east; the River Abbai lies perhaps about a mile to the north-east. The point is opposite Arafami waterfall, where there is said to be a ford at low stage.
8·8	$5\frac{1}{2}$	Path continues on the north side of the valley, which is wide, with a floor formed by the flow of vesicular basalt lava. There are views across to the south-west and the floor where the Andassam flows is certainly lower than that on which the path runs. There does not seem to be as great a fall to the Nile to the north-east and if this is the case the river is being held at a higher level by the ridge of basalt. The country is open, with patches of trees. The soil is dark and is certainly swampy during the rains. After the rains it is covered with grass about 2 metres high.
10·9	$6\frac{3}{4}$	About $1\frac{1}{2}$ kilometres south of the path is a spring, Amed Ambo, said to be saline, where cattle are taken to drink.
14·1	$8\frac{3}{4}$	River Andassam, at the ford about 30 metres wide and 90 centimetres deep. The width is unusual owing to an island and upstream it is not more than 20 metres wide. Like many of the streams the worst part of the ford is the muddy bank. The middle of the bed of the stream is firm, but when mules are on the verge of getting out they sink into very deep mud. There are alluvial deposits alongside the Andassam, which is flowing almost due east.
14·5	9	Proceeded to south-east; the path skirts a spur of horizontally bedded volcanic rocks, which runs out from the south-west side of the valley in an easterly direction and has constricted the vesicular basalt flow. The flow has rounded it and continues to form the floor of the valley. To the north there are views up a tributary valley with sides of red bedded rocks which appear to be tuffs. To the east these form the peaks of Doal and plateaux behind them, while to the west the church of Abuna Hara stands on a prominent point of what is a scarp of these red tuffs. They are much sculptured by water and are evidently soft rocks.
16·1	10	Left the main road to camp on east face of spur at an altitude of 1,750 metres. Here, the roar of rapids on the river could be heard in a direction to the north. South of the spur is the valley of the Yedoakt, the stream lying about 500 metres south, and flowing east. The valley floor is open grass land with patches of trees and palms. The only conspicuous large trees are Ficus. There are also cordias, combretums, gardenia shrubs and little groups of phœnix palms. Alongside the Nile and other water courses there are belts of forest. Returned to the track and continued south-east through h'gh grass, which caused some loss of time.

Kilometres.	Miles.	
18·5	11½	Small stream.
20·5	12¾	Another small stream.
22·5	14	Stream with about 20 centimetres depth of water. Most of these have beds about 10 metres wide exposing vesicular basalt.
23·3	14½	Stream.
25·3	15¾	Camped on plain, altitude 1,730 metres, just above the bridge, Agam Dildi, altitude 1,690 metres, which is reached by a steep path. The vesicular basalt of the Bahrdar Giorgis flow continues to form the wide even floor of the valley. This slopes fairly steeply eastwards near the spur east of the Andassam, but for the rest it continues with a distinct slope towards the south-east in the direction of the valley. Continued by a path going south-west across the plain.
27·4	17	The foot of the hills bounding the plain is reached and the path skirts them, passing to the north-west along their base. From the plain above the bridge several other paths were conspicuous on the hills, but this one does not climb them in sight of it.
28·2	17½	The path turns to the south and, crossing a small stream, proceeds up the valley to—
29·0	18	The pass, at altitude 1,760 metres, which separates the small valley from that of the Tul, and after crossing it the path descends along the west slopes of the valley, keeping parallel to the valley. The rocks of the slopes are horizontally bedded, compact with an extensive bed of grey tuff rather similar in appearance to the dressed stone of the arches of the bridge.
35·8	22¼	Turned off the main track and went a short way up a tributary valley to Birbirta at 1,840 metres above sea level. Returned and proceeded south-west along main road. There is coarse tuff in stream beds.
37·8	23½	Stream with a little water on a stony bed. The path then ascends steeply for an hour with many zigzags, altitude 2,160 metres, to—
39·4	24½	The top, altitude 2,170 metres. The path then traverses a plain.
47·5	29½	The track passes on the east of the lion-shaped hill of Abolai Nigus north of Zarabruk.
57·5	35¾	Zarabruk the headquarters of Fitaurari Amarro.

Kilometres	Miles.	
59·6	37	Altitude of camp 2,350 metres; the path proceeds towards the south-west. Three small streams were crossed before reaching this point.
62·0	38½	The track continues on the west side of the Shirah or Shinna valley, crossing tributaries.
64·0	39¾	Stream.
65·2	40½	Stream.
65·6	40¾	Stream with difficult muddy sides.
67·5	42	Crossed Shirah flowing north-north-east, altitude of bank 2,480 metres.
69·6	43¼	Small stream with rocky bed; the path continues to climb steeply.
76·1	47¼	Top of pass over the Amedamit Mountains. The pointed hill is Amedamit, the plateau to the north-west is Kosobarr. The altitude is 3,710 metres. The path then descends near the Ambomeida Rock.
86·1	53½	Gomb, altitude 2,370 metres, about a mile north-east of Ambomeida. Proceeded on east side of the valley which is said to be the wrong path, the usual one being on the west side of the stream. The eastern one is probably shorter, as returning messengers were met on it. A number of small streams were crossed, generally with acacias and small phœnix palms. The valley floor is about 2 kilometres wide with homesteads and patches of cultivation on the lower slopes. The flat part is covered with high grass and is doubtless water-logged during the rains.
115·0	71½	Altitude 1,970 metres; the path continues through grass two metres high on the valley floor and afterwards rises on to a spur on the east side of the valley towards the south.
121·1	75¼	A pass to a valley to the east is crossed. To the south is a double-topped hill. On the east side of the pass the track skirts the hill in a gentle descent. It then continues south across another valley showing bedded basalts on the east side while the west is low and open. On the east side of this valley the path rises.
130·3	81	The summit of a wide ridge across which a good path continues south through grass more than two metres high. A view of the Dembetcha Hill is obtained from the east side of this ridge.
137·6	85½	Stream about 2 metres wide.

Kilometres	Miles.	
138·4	86	Ridge west of Dembetcha with views of the Amedamit Mountains to the north-west and the spurs stretching southwards into the plains on the west. Several small streams were crossed.
140·0	87	Altitude 2,130 metres, path continues through wood and over bouldery streams.
148·0	92	Entered Dembetcha and traversed the village by bouldery paths deep in mud.

ALTERNATIVE PATH FROM DEMBETCHA TO AMEDAMIT.

(November 1920.)

0·0	0	Den market. The route following the Bure road from Dembetcha to this point has already been described in the route from Addis Abbaba to Bahrdar Giorgis. The path branches to the north-east, crosses the valley, skirts a spur and then turns north-east. The trees include *girror* acacia and the small phœnix palms. The path afterwards turns northwards into the Birr valley.
6·4	4	Bowoti, altitude 1,950 metres, is about a kilometre south-east of Marmiti Rock, a conspicuous rock which stands up as a sentinel on the valley floor in front of a spur. It is formed of horizontally bedded basalt. The path skirts the east of the spur for a short distance before turning north-east to cross the—
8·8	5½	River Birr. In December this was 12 metres wide, about 0·30 metres deep and was discharging about 2 cubic metres a second. The path continues in a direction slightly east of north up on the east side of the Birr valley.
33·0	20½	Enanja, altitude 2,270 metres. Gumbelli market is just to the north of this. The path climbs up zigzags, and passes well to the east of Ambomeida Rock.
39·4	24½	It reaches a col at 3,230 metres altitude and passes into a valley draining east.
45·9	28½	The path continues northwards to a pass on the south side of the Amedamit Mountains at an altitude of 3,710 metres.
47·9	29¾	Joins the track that has followed the upper part of the Birr valley and passed west of the Ambomeida Rock. It was taken on the journey from Bahrdar Giorgis to Dembetcha and is described in that report.

ZARABRUK TO BAHRDAR GIORGIS.

(November 1920).

Kilometres.	Miles.	
0·0	0	The path turns off to the north-west towards Debra Mai and goes over ridges in gently undulating country with views towards Rim.
13·7	8½	Debra Mai. The path passes on the north-east side of this large village, which stands on a low hill.
20·1	12½	The descent from the plateau 2,250 metres above sea-level begins and continues steadily through a valley in a general north-west direction.
37·4	23¼	River Andassam, about 7 metres wide and 0·40 metres deep with a discharge of about 2 cubic metres a second, is crossed and here the vesicular basalt of the Bahrdar Giorgis lava type is met with. The track is bad and winds in and out among forested hummocks of lava.
47·5	29½	Camp about 1 kilometre south-west of Bahrdar Giorgis village.

GENERAL DESCRIPTION OF THE COUNTRY FROM BAHRDAR GIORGIS TO DEMBETCHA.

The path down the Blue Nile valley from Bahrdar Giorgis passes over the floor of a wide valley flanked by hills of bedded volcanic rocks. The floor is formed by the surface of the modern basalt lava flow which has blocked this part of the valley. This feature appears to end about a mile below the Agam Dildi (bridge) and most of the surface is formed of good soil. This is of interest in regard to the depth of Lake Tana and is referred to in Chapter IV.

The plain is about 40 metres above the level of the roadway across the bridge and this is reached by a steep path. There is a small fall in the river just upstream. This shoots the water into the narrow rift spanned by the structure and it continues with a violent rush between vertical walls of amygdaloidal basalt. On the east side of the channel the wall rises about 6 metres above low stage water level to a platform, part of which is sometimes flooded. The narrowest part of the channel is towards the south and the actual position of the bridge was doubtless determined by a mass of rock which rises two or three metres above the general level of the platform. The main arch with a span of 8 metres crosses the narrow channel. There are three little arches in the part over the high rock and four other arches over the lower part of the platform towards the eastern end of the bridge, making a total of eight arches. A section of the bridge is appended to Mr. Dupuis' report.(1) The bridge is not straight but is distinctly convex downstream. It spans a place where the river happens to flow northwards and this leads to some confusion regarding orientation. The people regard the river as flowing generally southwards, therefore the right bank is on the west, and they still refer to the right bank as being the western one, where the river happens to be flowing north. The consequence is

(1) "Report on the Basin of the Upper Nile," Sir William Garstin, London, 1904.

that the west end of the bridge is pointed out as being towards the east. Lobo [1] relates that the bridge was constructed by one of the stone cutters brought from India for the purpose of building churches in Ethiopia during the reign of Segued, A.D. 1632–1665. Along the bridge there are still pieces of the parapet, which must formerly have had a height of about 1½ metres above the present road surface. On Ras Gugsa's side, at the western end, is the remains of a gateway just west of the main arch. There are traces of a cobble pavement, but the roadway is in bad repair and has been worn down almost to the arches. Trees are allowed to grow on the masonry and a large block which has fallen in the eastern arch may have been prized off by the action of roots. The structure will certainly be destroyed if the growth of plants on it is allowed to continue. It is built of ordinary basalt stone and lime, but the arches for a thickness of 80 centimetres have been constructed in ashlar cut from a soft, light-grey, banded kind of basalt which was evidently easily worked. It is said that plenty of such stone is to be found on a hill not far to the south-west. The arches are at right angles to the direction of the bridge and consequently diverge downstream. The rock channel opens out to 10 or 12 metres in width north of the bridge. At Mota there is another bridge, probably built at about the same time as the Agam Dildi, but it was broken for many years. It was repaired a few years ago by masons sent from Addis Abbaba.

The top water level of 1920 had left a white mark about 2 metres above that of the water on November 11, which was 13·10 metres below the roadway over the main arch. To the south, upstream of the bridge, the bank is formed of boulders and large irregular blocks of basalt. On these there is a black polish up to about 1 metre above the 1920 flood-level, suggesting that the river sometimes rises to that height. The people state that when the river was full in 1920, water passed through the eastern arches of the bridge. There was, however, no obvious sign of its having done so, and if it does, the occasion must be unusual. The depth of the water in the narrow channel spanned by the bridge is not known, but it could be easily sounded at low stage. The rush of water is less violent in the wider part of the channel a little way below the bridge, and here, where the depth is probably not much different, the river might be sounded when the current is too strong to permit measurements below the bridge.

The amygdaloidal basalt which forms the country rock on which the bridge stands contains masses of carbonate, filling large steam cavities. It differs in character from the vesicular basalt of the modern lava which covers it and forms the surface of the plain above the river.

The Tis Esat waterfall in the district of Alata is about one or two kilometres upstream of the bridge and its spray could be seen rising like smoke during the cold hours of the early morning. During the hotter part of the day the spray evaporates and is no longer visible. There is said to be dense forest near the waterfall and time did not permit it to be visited. The fall has been visited and described by many travellers, including Jeronimo Lobo and Bruce [2], who refers to it as the most magnificent sight he ever beheld. Ostini saw it at a very low stage of the river when it was not at all impressive.

On the left bank of the river, about three kilometres north of the Agam bridge, there is said to be a hot spring which is good for various diseases and which has been patronized both by Ras Gugsa and Ras Hailu. Its water is said to come out in a regular cascade.

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(1) "A Short Relation of the River Nile," translated by Sir Peter Wyche, London, 1669.

(2) "Travels to Discover the Source of the Nile," London, 1790, Vol. III, p. 425.

The existence of a hot spring at this place, which must be a considerable height above the river, is of interest in regard to the origin of the water and its heat. If it is due to surface water, there must be hot rocks to supply the heat.

The sides of the lower part of the Tul valley are formed of horizontally bedded lava and tuff. Columnar parts of the flows with scoria above and below are well exposed on the steep slopes. There was a coarse volcanic breccia exposed just below Birbirta and in stream beds to the south-west. The valley is wide, and its floor below the steep sides is all fully cultivated. There are good views in the course of the ascent from the Tul valley and, at its mouth, the Nile valley is seen to be quite narrow towards the south-east.

On ascending out of the Tul valley an extensive vista of the plateau above is obtained. This has been cut into by the head of the Tul, which forms a sort of corrie with the plateau above it. A few small hills rise from the surface of the plateau and prominent among these is the lion-shaped Abolai Nigus, near which there is a hot spring. The hill is situated north of Zarabruk, the " head " appears to represent a volcanic vent, while the other part of it is stratified. Beyond, to the south, rise the slopes of the Amedamit Mountains.

Crossing the pass over the Amedamit Mountains, these were seen to be formed of horizontally bedded basalt flows with some dykes and tuff. There is rotten basalt at the pass. In clear weather there are good views of the lake, and the island of Dek is seen to be quite extensive. In December the atmosphere was clouded with dust up to a level which appeared to be about that of the highest peaks, about 3,800 metres above sea-level.

Wheat is cultivated on the high ground just below the pass and the local plants include larkspur, impatiens, two kinds of hypericum, veronica, mint, geraniums, heaths with white flowers, wild roses, junipers, " red hot pokers " *Aloe Abyssinica*, and composites are represented by yellow "everlastings," white corn flowers, a plant with pale blue, well developed florets, and many others.

At the head of the Birr valley near the Ambomeida Rock a cultivator was found irrigating a plot of red pepper by means of water diverted from a small stream. This appears to be a common practice, as it is necessary to have seedlings ready to plant out when the rainy season comes. If the water cannot be made to flow on to the land, it has to be laboriously carried.

About 23 kilometres from Ambomeida down the river valley on the east side there are smooth, dome-shaped spurs which at first suggest sculpture by glaciation, but they prove to be dome-shaped on their downstream sides as well. The valley sides are formed of basalt bedded with a slight dip of one or two degrees from the high mountains to the north. A similar dip is very well marked in the beds forming the west side of the valley and points to the lavas having been poured out from a centre at the Amedamit Mountains.

Bahrdar Giorgis to Lebbo and Delgi

ROUTE REPORTS.

BAHRDAR GIORGIS TO LEBBO.

(December 1920).

Kilometres.	Miles.	
0·0	0	Left Bahrdar Giorgis. Path goes east-north-east.
3·2	2	Kamforo ferry crossed by means of papyrus boats, *tankwas*; path turns north and then north-east, passing close to marshes east of Debra Mariam Lagoon.
7·2	4½	Altitude of Lij Balai's village 1,860 metres, on slope opposite north outlet of Lake Tana. Path goes slightly east of north over low ground and there is a bad river crossing with deep mud.
11·3	7	Path goes over ridge of compact basalt. The going is very bad through dense scrub.
13·3	8¼	Igasha river about 2 metres wide and 0·20 metres deep.
14·5	9	Met another path running north-east to south-west; the Obit Bata Church stands to the north-east and there is a stream just north of it.
19·7	12¼	Two small streams are crossed south of this point. The country is a gently undulating plateau.
22·9	14¼	Gelda river, 8 metres wide 0·2 metres deep with a discharge of about one cubic metre a second. The valleys are flat-floored and there is much tall grass.
26·2	16¼	Path turned east.
30·2	18¾	Path turned north.
31·0	19¼	Path turned east.
33·0	20½	Higher point on plateau.
33·8	21	Path passes close to Kudus Mikail Church in a big grove at Zara, 1,960 metres above sea-level.
37·4	23¼	From here the path descends to the north-north-east to the Fogara plain. This is an extensive alluvial plain with an indiscernible slope from the hills to the shore of the lake. There are a number of villages on it. The path continues north-east.

Kilometres.	Miles.	
42·7	26½	Gumara river in December was 30 metres wide with an average depth of about 1 metre and the flow early in December was about 0·1 metre a second, giving a discharge of about 3 cubic metres a second. The greatest depth was 1·5 metres. The pack animals had to be unloaded and the loads carried across by men. The flood level of the stream is between 2 and 2½ metres above the December water level. The bottom is of pebbles up to about 5 centimetres in diameter and the sides are formed of mud and rise about 3½ metres to 4 metres above the flood level. The river does not fill the present channel as a rule, even in flood. Just east of the ford is a church in a grove with a conspicuous, tall eucalyptus tree. The path continues north-east.
52·3	32½	Erza river, with a discharge of about 0·1 cubic metre a second. Path continues north-east.
54·3	33¾	Warata market is situated on a ridge which extends west for about 500 metres into the plain. The path descends to the north-north-east and continues northwards.
57·5	35¾	Turned off to the foot of a spur, altitude 1,850 metres. From the top of the spur there are views over the Reb portions of the Fogara plain to the north and these are seen to fill a bay running east into the plateau. They are bounded on the north by high hills. The spur is formed of compact basalt and the villages obtain their drinking water from springs at the base. The path continues northwards from the spur.
60·8	37¾	South of this point two streams with muddy beds winding across the plain are crossed. Their combined discharge was probably about a tenth of a cubic metre a second.
61·6	38¼	The River Reb proved to be 15 metres wide, 0·40 metre deep with a velocity of about 0·2 metre a second, giving a discharge of about 1 cubic metre a second. The channel is narrow, canal-like, and in flood the water rises to about 4 metres above the December water level. The top of the channel is 2 metres above the flood line. Path continues across the plain.
65·6	40¾	Entered forest of *Acacia seyal*, Ar. *talh*, on rather high ground.
67·6	42	Stream discharging about 0·05 cubic metre a second. Basalt is exposed in its bed. The edge of the plain is being approached and the ground is rising slightly. The *talh* scrub continues.
69·6	43¼	Edge of the plain. The path rises to the north-north-east on a basalt ridge to—
71·2	44¼	Ifag, situated on the east side of the crest of the ridge. It is a large village and the market is held on Wednesdays. The telephone line from

Kilometres.	Miles.	
		Debra Tabor to Dankaz passes through. The path continues in a north-east direction and crosses several small streams which are certainly the tributaries of the Reb previously crossed.
83·3	51¾	Shini river at Kwai Namas 2,100 metres above sea-level. The latter part of the path has been up the floor of this valley and big hills of stratified volcanic rock are seen at its head. The stratification is not very distinct. There is a kind of red tuff in the stream bed. The main road on the north-west side of the valley was left but a path to the east across the Shini was taken, and it continues up the other side of the valley winding along ridges.
88·9	55¼	Joins main road, altitude 2,540 metres above sea-level. The path trends north and climbs steeply. There are magnificent views.
89·7	55¾	Altitude 2,860 metres above sea-level.
93·0	57¾	Altitude 2,970 metres above sea-level. Edge of plateau but path enters over small pass, altitude 3,030 metres, and proceeds north-east up a grassy valley.
95·4	59¼	St. George's church, Lebbo, altitude 3,430 metres. Ras Gugsa had made his headquarters about a kilometre east of the church and was rebuilding a Gibbi on an old site about 3 kilometres south-east of the church. The Lebbo ridge has an undulating surface with villages and cultivation. The church is surrounded by a thick grove of juniper trees.
97·0	60¼	From the church the Dankaz path was followed in a westerly direction to a stream, altitude 2,970 metres, at a convenient distance from the temporary population of chiefs and retainers centred about the Ras.

Lebbo to Delgi.

(December 1920).

Kilometres.	Miles.	
0·0	0	Starting from the camp about a mile west of St. George's church, Lebbo, the path goes west-north-west down to a col, from which it ascends to the north-north-west up a steep slope to the north of a hill and passes over a shoulder. Altitude 3,580 metres.
5·6	3½	Another pass at altitude 3,630 metres and track crosses to south-west side of ridge after passing to the north of a hill said to be called Lebbo and certainly the highest in the district.

Kilometres	Miles.	
13·7	8½	Wahinni, the prominent hill seen from the south side of the lake, is passed on the south-west side of the path. It is trachytic. The track is a big one and is very circuitous in going round the slopes of valleys.
22·5	14	The path continues along the ridge, altitude 2,890 metres, which is here formed of basalt.
26·6	16½	The telephone line from Ifag to Dankaz is crossed at the Gumoha stream. The soil is red and the altitude is about 2,830 metres. The track is often deeply cut and has evidently been subject to much traffic for a long period. At this point, the path followed, branched off to the west of the main track, which continues north-west. The path goes westwards along high ground with many wild olive trees.
30·6	19	Top of the descent. The path descends steeply to the west. The olive trees are left behind and towards the foot *Acacia seyal*, erythrinas, gardenias and large Ficus trees are met with.
37·8	23½	Foot of slope at 2,200 metres. Path traverses open country in a westerly direction.
48·3	30	*Acacia seyal*, Ar. *talh*, forest on black soil extends 3 kilometres.
51·5	32	Shore of Lake Tana.
53·9	33½	Path leaves the shore and proceeds westwards.
58·4	36¼	There are views of the Dankaz–Lebbo Hills with horizontal stratification. Gondar was seen on the lower slopes some distance to the north.
60·0	37¼	Meandering stream in black soil, bed about 10×2·5 metres, dry in December.
66·0	41	River Magach, 5×0·4 metres, discharging about 1 cubic metre a second. The bed is 5 metres below the level of the plain, formed of basaltic sand and gravel, and the channel is generally about 10 metres wide. It is flanked by marked berms. The discharge during flood must be considerable. The road turns north-west along the bank of the river.
66·8	41½	Achara Mariam church. The berms are fully cultivated and there are villages near the stream. The path turns and continues west.
75·7	47	Dirma stream with muddy bed 5 metres wide and 0·3 metre deep, discharging about 0·1 of a cubic metre a second. The channel is about 10 metres wide and 2 metres deep.

Kilometres.	Miles.	
77·7	48¼	Edge of Dembia plain. The path rises on to the Gorgora Hills. The name Dembia is pronounced with distinct emphasis on the second syllable and refers to the country east of the Gorgora Hills. The main paths run from village to village and it is very easy to take the wrong track.
78·9	49	Camp site, altitude 1,880 metres, near small stream. Path continues west over undulating country.
86·9	54	Alugsa stream discharging about 0·5 cubic metre a second on rocky bed.
90·2	56	Alluvial plain on west side of Gorgora Hills. Path continues west.
92·2	57¼	Abaganan in muddy bed, stagnant, channel about 7×2 metres.
94·2	58½	West side of plain, path turns south-west on low ridge. A diversion was made to Alloha and the distances on the direct route have been scaled from Col. Pearson's map. Alloha is on a basalt ridge running southwards and ending with a conspicuous knoll on its east side. It is separated from the lake by a flat belt of alluvial deposits about 500 metres wide. A path goes to the south-west, crosses a valley, then a ridge and joins the main track, which descends towards the south-west on to an alluvial plain. Here there is a distinct storm beach of quartz sand.
108·7	67½	A stream draining from the north is crossed.
109·1	67¾	Just beyond is the vesicular basalt ridge on which Delgi is situated. The ridge is about 400 metres across from north-east to south-west and south of it is a bay with a very well marked storm beach. The village is large for Abyssinia and is important owing to its position on a junction of trade routes to Gondar, Dangila, and Gallabat.

Around North-East Shores of Lake Tana.

(December 1920).

Kilometres.	Miles.	
0·0	0	Achara Mariam. The path from Delgi joins the path from Chilga and Gallabat.
12·9	8	Shore of Lake Tana, path continues along the shore.
16·1	10	Path leaves the lake shore, which is marshy, and passes about a kilometre south of the ruined church of Geraicha Arbatanza, situated on a small hill. On the shore, south of the church, is a small deposit of sand. From here the path rises to the east-south-east through low hills.

Kilometres	Miles.	
22·1	13¾	Pass at altitude 1,940 metres, where the Ifag-Gondar road is met. The path then turns to the south.
26·6	16½	Lake shore. In this region there are a number of rocky points with bays between them.
33·0	20½	Small stream with muddy bed and no flow. A plain is reached.
33·8	21	Stream about 10 metres wide and 0·3 metres deep discharging about a cubic metre a second.
37·8	23½	Path passes through line of small hills on to another plain.
38·6	24	Path continues along the shore of a bay. The shore is formed of basaltic sand, which continues at least 1½ kilometres to the south and is clearly extensive.
41·9	26	Opposite a spur running out from the east. The shore of the lake here is sandy and there is a large quantity available. The path continues south.
45·1	28	Turns to the south-south-east alongside a stream with a marshy bed.
47·9	29¾	Path rounds the last foot-hill and reaches the Fogara plain, which is actually continuous with that already traversed to the north-west of the hills.
48·3	30	Small stream and path goes first south-east and afterwards east, as the lower part of the River Reb was not fordable in December. It would be better to turn off from the lake sooner or even to follow the Ifag road for some distance before turning south-east.
60·0	37¼	Abbo Yesus ford across the Reb is just east of a church with trees and reeds. The road from here goes south, passing about 200 metres west of the spur 3 kilometres north of the Warata market.
67·6	42	Warata market passed on other route.
68·4	42½	Small stream, altitude 1,860 metres. The path goes south by a very devious route.
78·1	48½	Ford across Gumara followed the former route.
82·9	51½	Edge of plain.
86·5	53¾	Zara Church.

Kilometres.	Miles.	
88·5	55	Diverged from other route. This was to avoid the bad going south of the Igasha river on the path nearer the lake shore.
93·4	58	Stream at Matanza. The track is not well defined and goes in a south-south-west direction over undulating country with a gradual descent in the valley.
96·6	60	River Gelda discharging a quarter of a cubic metre a second.
98·6	61¼	Another small stream flowing west.
99·4	61¾	Gombat Kudus Mikail Church. The path turns to the south-west, passes another church, Debra Zion, and descends south-west along a bad path.
115·5	71¾	Chimbil stream.
116·3	72¼	Kamforo ferry across Blue Nile.
119·5	74¼	Bahrdar Giorgis.

General Description of the Country from Bahrdar Giorgis to Lebbo and Delgi.

The country on the east side of the lake north of the outlet is gently rolling, covered with red soil and bears vegetation. It has the appearance of yielding a small proportion of run-off. It slopes down from the east and on the east of the path there are some small volcanic cones.

The Fogara plains are flat, alluvial, and fill a wide bay about 300 square kilometres in extent in the hills on the eastern side of Lake Tana. They are traversed by the Rivers Gumara and Reb as well as by several small streams. These, especially the larger, are flanked by berms which are drained and are either cultivated or bear relatively short grass. The hollows between the rivers must, to a large extent, become water-logged during the rains, as they cannot drain to the stream channels. There are numbers of villages and in December many cattle were grazing. The cultivation on the river berms is quite extensive and it is evident that a considerable population remains on the plain all the year round. There are very few trees and these are principally either cordias or acacias. The flatness and extent of these plains, with villages and few trees, bounded by distant hills recall the landscapes of the Egyptian delta, only palm trees and pumps being required to complete the similarity. The soil of the plain is black in contrast to the red soil of the slopes at Zara on the south.

The people are correct in relating that the lake once covered the whole area and extended to the hills on the eastern side of the plain, for it has all been deposited by the streams. It is improbable that the growth can have been fast enough to have been appreciable within human lifetimes. Doubt must be cast on the statement of an old man who said he remembered as islands, certain hills which now rise from the alluvium at the

mouth of the Gumara. D'Abbadie's topography, which was evidently carefully surveyed, differs too much to allow points on the lake shore to be identified on the recent map. The bearing of the evidence of these plains on the question of the age of the lake is discussed in Chapter IV.

The lower part of the Shini valley proved to be formed of a solid red volcanic tuff or conglomerate of a coarse texture. The presence of this rock seems to account for some of the pinnacles which are common along the south face of the Lebbo range, the harder material of dykes and intrusions standing out like towers or castles. Above the tuff are horizontally bedded basalts with columnar jointing. From the road on the east side of the Shini valley north-east of Ifag there are views of the east shore of the lake. The Korata rocks are seen extending out into the lake at the southern margin of the Fogara plains.

Lebbo is situated on a flat-topped ridge extending from north-west to south-east, with steep descents and often cliffs on both sides and separating the Setit basin from that of the Abbai. The description as " flat-topped " is only partly true, as the surface is undulating with many valleys, but the general level is about 3,400 metres and some hills rise to about 300 metres higher, or total heights of about 3,700 metres above sea-level. One of these is a flat-topped hill Angerdibba. The top of the ridge is formed of a bed of grey trachyte, more than 300 metres thick, which is responsible for the crags and precipices along its edge. The rock sometimes shows a flow structure with different directions in various places. Near a stream immediately to the north-west of Angerdibba it was vertical, with a north-west to south-east direction, and the rock split along it almost like a schist.

The vegetation includes heaths, acacias, and scabiosa. A little bracken and much maidenhair fern were seen towards the top on the path up. The views with the heaths were similar to those met with at altitudes of about 1,000 metres in Madeira. Barley is extensively grown on the top of the plateau. The acacia trees on the plateau are the *girrar* kind, with its peeling, papery bark on the younger branches, while the older ones are covered with lichens of various kinds, including " old man's beard " and a few orchids, all testifying to the dampness of the climate during the rains. In December, in contrast, the climate is very dry and this was confirmed by the dust hazes which obscured the view on several days. The dust haze forms a layer with its upper surface between 3,000 and 4,000 metres above sea-level and the distinctness of this surface is very marked in the horizontal rays of either setting or rising sun. There is a dull grey belt with an upper part reflecting red rays grading fairly sharply into the clear blue sky above. It seems improbable that winds raise the dust, but possibly the explanation, like that of some of the windless but hazy days of Egypt, is to be sought in an electric effect.

From the Lebbo ridge there are very extensive views in almost all directions. To the north the ridge overlooks the basin of the Belesa, one of the tributaries of the Takkazye (Setit). The greater part of the basin appears to slope evenly, broken only by a few striking pinnacles rising from its floor, which is perhaps 1,100 metres below the level of the ridge. The horizontal plateau structure is well displayed and river beds appear to be cut deep below the floor. Beyond the basin to the north are the Simyen Mountains, which can be seen as a great plateau-like mass without any striking features to denote their great height of 4,600 metres. The Lebbo ridge falls towards the east and there is a much broken region of hills which extends southwards to Debra Tabor and the hills behind. To the south are the Fogara plains with the lake to the west. The southern edge of the plains is formed by the Wanchet Hills, a low range rising to heights of about 500 feet above

the plains and terminating in rocky points with islands beyond them in the lake. Right away in the distance, the view to the south is bounded by the Amedamit Mountains and nearer are Abuna Hara and Zegi. In the lake are the islands of Dek and Degga, the outlines of which are shown up when the afternoon sun is reflected from the lake. To the west there are views along the northern edge of the lake with its embayed shore and the Gorgora peninsula—its ragged end running out and terminating with islands beyond it. The lake on the far side of the Gorgora peninsula could be seen, and also the line of hills on the western shore which form the narrow divide between the slopes that go down towards the Sudan.

At a col about a kilometre west-north-west of the base of Angerdibba is a trachytic breccia which appears to mark the base of the flow. To the north-west, on flat ground beyond a shoulder, the surface of the trachyte is pitted with basins, perhaps owing to the decomposing action of turf, and hummocks stick up at intervals between. There is no evidence of glaciation in these mountains.

The climate at these altitudes is quite cold in winter time and during December there was a hard frost every morning. It is, however, the dry season and there is little water to freeze. The rain falls during the summer months when the climate is warmer and the ground is dry long before the cold weather of the winter sets in. Perhaps for these reasons the Simyen Mountains are free of snow and the absence of traces of glaciation around Lebbo and in the Amedamit Mountains is certainly due to there never having been any extensive glaciers. There may have been snow fields.

There are some high hills to the north-west of Lebbo and all are formed of trachyte. This extends to near the point where the Ifag-Dankaz telephone line is crossed. Beyond, there are exposures of basalt. Views of the lake from the top of the ridge about 19 miles north-west of Lebbo show that the shore is generally low, and along the northern edge, east of Gorgora, it contains four bays and is marshy.

The north-east of the lake is flanked by foot-hills with bays filled with level plains of alluvial deposits. The spurs of the hills are usually separated from the lake by belts of alluvium. There is a large quantity of basaltic sand in this region and it certainly exists in other places besides those noted in the route report. The presence of the sand is certainly related to the proximity of the Lebbo-Dankaz range, from which torrents reach the lake. The sand often forms a storm beach at high water level and it may be separated from the low stage level by a belt of marsh with sedges at the water's edge. This region is worth consideration as a source of sand for the construction of any masonry.

The horizontally bedded structure is well displayed on the slopes above the east end of the Dembia plain. The hard rock here is all basalt, but doubtless there are scoria and tuff which do not show. The soil on the plain at the foot of the hills is black. From the plain there are views of the range of high hills stretching from Lebbo to Dankaz. In several places, especially below Dankaz, the topography is that of "bad-lands" and suggests the presence of rocks softer than the basalts and trachytes. Horizontal bedding is very distinctly displayed. It seems probable that the base of the range in this direction is formed of a mass of tuff such as that seen on the road north-east of Ifag and also below the trachytes on the way north-west from Lebbo. The trachytes are only to be regarded as forming the culminating points of the range.

The Dembia plain, like the Fogara plain, is obviously alluvial. The surface is of black, cracked soil resembling the *badob* of the Sudan, and where it is not cultivated it bears grass 2 to 2½ metres high, which dries after the rainy season and is burnt off early in the

new year. The plain must have a marked slope down to the lake, as shown by the velocities of the streams. These have definite berms and no run-off from the land alongside can enter them. The presence of a permeable subsoil is demonstrated by the village wells on which the people depend for their supplies. The permeable bed is at a depth of about 5 or 6 metres and its nature is probably similar to the gravel in the bed of the Magach at Achara Mariam. The marshy shore of the Dembia plain is shown in Photograph 13 and the spurs of the Lebbo range appear beyond the water.

The plains are bounded on the west by the Gorgora Hills, the eastern margin of which is formed of scoriaceous basalt. From the hills there are good views over the plains and they appear to be about 30 kilometres from east to west and 10 kilometres wide on an average. The Gorgora country is typically undulating without any conspicuous hills. There are no points rising to above 2,200 metres.

On the west of the Gorgora Hills there are streams traversing alluvial plains and on approaching Delgi, quartz sand is met with on the lake shore. This sand has doubtless been derived from the sediments known to exist towards the north. The presence of this quartz sand suggests that there must be outcrops either of the old crystalline rocks or of Nubian Sandstone at high levels in the country towards the Eritrean border.

The presence of the quartz sand has led to the formation of storm beaches along this part of the lake. Basalt rock weathers into soft clay, and the action of the waves cannot pile it up to form a ridge a little above high water, and as a consequence the shores are low around most of the lake. Sand, on the other hand, stands with good slopes and the result is that in this part where it prevails there are storm beaches. There is a well marked storm beach south of Delgi stretching along a bay. There are little sandy bays among the rocks at Delgi and on these are numbers of shells, including *Melania tuberculata*, *Corbicula* and perhaps *Ampularia*.

Delgi appears to have a distinctly drier climate than Bahrdar Giorgis and there are fewer mosquitoes. The cattle during the night were kept in pens on the rocks and in such places at Bahrdar they would have been driven mad by mosquitoes.

The vegetation on the plains and low hills near the north-west corner of the lake includes both *talh*, *Acacia seyal*, and the *girrar* acacia, bauhinias, cordias and a few gardenias. Cassia bushes were conspicuous with flower in December, but the proportion of trees is very small and there is really no timber. The uncultivated country is almost entirely covered with high grass. No papyrus was met with along the north shore of the lake, but the margin is generally marshy with other sedges and grass, like Ar. *um suf*, which according to Broun is applied in the Sudan to *Panicum pyramidale* and *Vossia procera*. A common sedge here stands about a metre high with a rosette of leaves at the top.

There is, as a rule, no distinct high water line or shelf along the shore of the lake, as the material is too plastic to allow the formation of a definite mark. The ground, however, appears to rise and it does not seem that much additional flooding would be caused if it were decided to hold the reservoir level up to 81·30 instead of only to 81·00 metres.

Along the northern shore of the lake there are many ruined churches, marking the Dervish raids. The ruins, perched amid groves of trees on hills, are often striking. Another sign of the raids is the presence of people with Arab tribal cuts on their faces. These were taken into slavery as children and marked with their owners' signs. There was a couple at Alloha. The woman after her capture had first belonged to Wad el Nejumi,

and when he met his fate at Toski, she was sold with the rest of his possessions. She described how she made faces to make herself look old to avoid being taken by another big Dervish Amir. She was bought by her husband, who also had been captured and was then one of the Khalifa's soldiers. They lived together until the battle of Omdurman. Then they returned to their own country, going first to Egypt, then by sea to Massaua, thence overland by Asmara, Aksum, and Gondar.

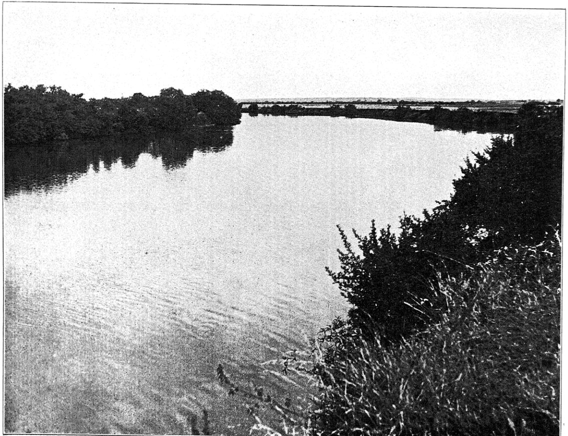
Bahrdar Giorgis to Roseires.

ROUTE REPORTS.

BAHRDAR GIORGIS TO ROSEIRES VIA ALAFA.

(May and June 1921.)

Kilometres.	Miles.	
0·0	0	Left Bahrdar Giorgis by path going in north-west direction between Sessala Abbo Church on hill to north and Debanji Hill to south.
11·4	7	Imfraz stream 15×0·5 metres, discharging about 1·5 cubic metres a second; path continues in a west-north-west direction rising on to country with red soil, altitude 1,890 metres, and passes about 2 kilometres south of a gently sloping hill with two small parasitic volcanic cones on it. The same type of country extends to the east slopes of the Little Abbai valley.
27·2	17	Little Abbai with a channel about 70 metres wide in a wide valley. There are well marked berms alongside the channel and marsh on the lower ground between them and the valley sides. The path continues westwards along the edge of the channel.
32·4	20¼	The Dambi ford across the Little Abbai is where there is a bar of rock forming a rapid in the stream. There are some small islands and the total width of the channel is about 100 metres. The discharge at the end of May was betwen 4 and 5 cubic metres a second. On the west bank of the river, the path runs south-west into country with low volcanic cones, and then goes west to Assiru Dabr. The traveller must avoid attempting to take what appears to be the more direct route to the north-west from the ford. There is country of basaltic ridges with swamps between them and where, for the most part, there is hardly any track. The going is extremely bad.
43·3	27	Assiru Dabr (Ten Churches), situated at altitude 1,850 metres on low slopes on the edge of marshes. North of Assiru Dabr is an extensive low-lying swamp above which rises Estomete Mariam, a volcanic cone. There is a good track which skirts the west side of the swamp, and is one of the main trade routes from Dangila. It first crosses an extensive plain with dark soil traversed by a small dry stream bed, where, even in the rains, there can be very little current, as the bed is of black soil. The country to the west rises, but except for some isolated hills, which are perhaps



No. 33.—The Little Abbai above the Ford near the Lake.

Kilometres.	Miles.	
		70 metres above the general level, the ground does not seem to attain any considerable height to the west of the lake. North of Dorche, the ground rises slightly, the soil is red and supports scrub of acacia and combretums with a few proteas. The path descends, crosses a hollow, passes the foot of an abrupt little hill of compact basalt irregularly jointed, as if it were an intrusion, and then rises.
55·1	34¼	Forohe is situated on a ridge probably about 70 metres above the lake. The path descends to the north and crosses the valley of the Wardi, where there is basaltic sand in the stream bed. This stream at the point where it was crossed, about 3 miles from the lake, is flanked by wide plains which are suggestive of alluvium, but the topography is opposed to such an explanation, and the soil is more likely to be the result of decomposition of basalt *in situ*.
64·2	40	Gabgabit at altitude 1,900 metres. From here the track goes north-west, crossing the Tukur Waha and several small streams. The path turns west-north-west, rises, and crosses the boundary between Ras Hailu's country and that of Dedjaz. Ayalewu, whose authority extends to Kwara and the Sudan boundary, including Gubba. The watershed is reached at a point about 5 kilometres from the lake, and the path continues north-west along slopes falling towards the west, and crosses the heads of several small valleys. The undulating country of the Alafa plateau is reached and the path turns west.
82·9	51½	Village of Fit. Daboch, altitude 2,300 metres. Water supply is obtained from a small stream in a valley close by on the west, altitude 2,220 metres. The path continues west over the undulating surface of the plateau, which is formed of red soil.
92·8	57¾	Faki Wanz is crossed flowing south.
94·5	58¾	Akli is a small stream, altitude 2,160 metres, flowing north. The path rises westwards on to the plateau about 70 metres above the stream, and turns to the north-west. Chara Giorgis Church stands a little distance away on the left of the path, which then goes north-west along a ridge with the scarp on the west and a deep valley on the east descending gently to 2,270 metres.
99·8	62	The first sharp descent occurs where the track passes over the eastern edge of the ridge and goes down a steep narrow defile for perhaps 15 metres of descent, down which mules have to be led one by one, but there are no real difficulties. Below this there is a good path on the slope along which mules can go easily in single file.
101·3	63	A little plain, altitude 2,130 metres, is reached farther on, and this is formed by the third bed of basalt counting from the top of the plateau.

Kilometres.	Miles.	
		The next descent is easy down to 2,110 metres, whence a gradual descent continues to 1,850 metres. From this point there is a steep descent over large boulders of basalt to 1,780 metres. There are some huts a little way to the west on the opposite side of a small valley, showing that a permanent supply of water can be relied on. Descending travellers might do well to make part of the descent on the first day and to camp near this point.
104·0	64¾	The Agam Waha, flowing north-east into the Bangun, is crossed at the foot of the slope. The path then ascends to 1,790 metres round a spur, and continues for an hour with few undulations along the south side of the valley. Several small streams were crossed, most of them with water, but this may have been the result of recent rains. There are villages on a level shelf on the north side of the valley. The path subsequently turns to south-west around the nose of another spur, altitude 1,820 metres.
111·1	69	Fingeta Abbo Church, said to have been destroyed by the Dervishes, is situated on a ridge separating the Bangun and Shimfa drainage from that of the Sidd. Just north of the ridge the path crosses the shallow valley of the Asharikura, altitude 1,770 metres.
111·6	69¼	The path crosses the ridge and begins a descent to the south-west.
112·0	69½	Head of a steep descent, 1,730 metres, which occupies 35 minutes. Parts of it are very steep and rough, the mules having to be helped along one by one, but there is no need to unload them. The uppermost bad stretch, where the path zigzags in and out among rocks, is known as the Wousha Tirs or "Dog's Teeth," and extends perhaps 30 metres in height, while the lower one is only a matter of about 6 metres. The path has taken advantage of the sides of a spur which extends out into the main valley, and the going is fair except for the two places referred to.
113·3	70½	At the foot of the steep descent is a shelf, altitude 1,360 metres, and this terminates the worst part of the incline. From it a gentle slope continues.
115·5	71¾	Fil Waha (hot spring), stream in a rocky bed which is crossed near the hot spring. The path then runs parallel on the south side.
117·0	72¾	Cultivation and villages are reached where the floor of the valley opens out. The altitude here is 1,180 metres. The descent may be recapitulated with time intervals from the start as follows :—

Hours.	Mins.	
0	00	Start from Akli.
0	55	Beginning of first steep descent from plateau, mules have to be led one by one down bad bit of path.

Kilometres.	Miles.	Hours.	Mins.	
		1	25	Shelf reached.
		1	35	Next descent begins.
		1	50	Descent becomes more gentle.
		2	05	Another moderately steep descent over large boulders begins. Village passed on left.
		2	15	Agam Waha at foot of descent, path rises from this point and runs along side of valley. The Bangun stream is just to north and there are villages on a shelf on the north side of it.
		3	00	Jeraman Waha, a small stream probably containing water all the year round. The going continues fair along an undulating path.
		3	25	End of spur, path turns west, descends, and crosses an open valley.
		3	45	Fingeta Abbo Church on ridge on south side of valley.
		3	55	Cross ridge from which path descends gently to south-west.
		4	00	Top of steep descent to south-west. Below this, the path descends rapidly for nearly 370 metres and this includes the most serious part of the descent.
		4	35	Foot of steep part of slope at shelf, from which a gentle descent continues.
		4	50	Bed of stream near hot spring, Fil Waha, from which path traverses gently undulating ground.
		5	05	Cultivation is met with.

The muleteers remarked on the excellence of the descent as compared with Daflit route, west of Dangila,* taken by Mr. Black and Mr. Herbert, and it was said to be as good as the descent from Barbarie Kura towards Gallabat. Later, when they started back, they announced their intention of ascending via Achafar to Dangila, which, they said, though not as good as the Alafa route, was not difficult for loaded mules. Most probably the attraction of that route was the avoidance of toll posts.

The path continues west along the valley.

119·8 74½ Sidd river flowing north-west is crossed, and the path pursues its way westwards over undulating rocky country, still in a valley bounded both to the north and south by hills formed by spurs running westwards from the escarpment.

124·8 77½ Sidd river is crossed again, this time flowing west. It has a bouldery bed in a deep rock channel about 20 metres wide with steep sides 13 metres high, suggesting that in flood it may carry 30 cubic metres a second. On May 31, the water was turbid as a result of recent rains, and the discharge may have been about half a cubic metre a second. In the dry season there

Kilometres.	Miles.	
		can be practically no flow, but possibly the bed contains pools fed by the hot springs above, as these are unlikely to be subject to seasonal change in volume. The path continues westwards, crossing several streams with pools of water on rocky beds, and these obviously cannot be depended on to contain water during the dry season.
138·5	86	The Shimel Waha a stream flowing west on a rocky bed, altitude 960 metres. Between these streams the country is flat, and there are patches of cracked black soil some of which are cultivated.
138·8	86¼	Jigra Waha is a larger stream and flows south, but on May 31, there was only water standing in pools, and these were certainly the result of recent rains. This is west of any village in the district. The path continues west and crosses two or three small streams draining south over rocky beds.
143·1	89	Kudkud Waha, altitude 940 metres. This is said to contain water all the year round, but from appearances after rain, when there was still hardly any flow, the permanence of water here is to be regarded as very doubtful. This river forms the boundary between the Alafa and Kwara districts. The path has been over gently undulating country with some areas of cracked black soil and continues west. The Bardanki plateau lies 5 or 6 kilometres south of this part of the route, and rises about 80 or 100 metres above the general level of the plain. It is obviously composed of bedded basalts, and is covered with small trees. Several small streams are crossed.
147·1	91½	The country becomes rougher with ridges rising and falling 30 metres or more between the streams.
153·8	95½	The Wambalasa flows south across such country and is joined by a tributary at the point where it is crossed.
154·4	96	The path meets the Sidd and runs along the bank. Altitude 810 metres. The bed, 50 metres wide, is of basalt boulders, and shows that in flood the stream rises about 4 metres. At the beginning of June there was a flow of only about ½ cubic metre a second. The track is over undulating country, the descents into tributaries being greater than the rises towards the west, showing that there is progressive falling in the level of the country. The river, altitude 800 metres here, lies in a valley bounded by considerable slopes both to the north and to the south.
175·2	108¾	The country becomes more open and less hilly. Some of the *Luban* trees along the route near this part have been tied in knots while young, and have continued to grow in this contorted form.

Kilometres.	Miles.	
188·2	117	Cultivation is reached at Kakrwaha. Villages beyond are situated on the lower slopes of some spurs of the Kwara mass, which towers up on the north. The local chief is Dedjaz. Umbibal (Umbiilal). The path continues below the flanks of low basalt hills over plains, altitude 780 metres, of black cracked soil, intersected by streams with rocky beds in deep channels.
206·6	128½	An abandoned site of Dunkur market. It appears that there have been several, including that on the Aima, to which the Sudan Government formerly sent convoys and that at present there is no regular market.
213·6	132¾	The path passes north of Um Zinegia, a prominent cone-shaped little hill rising beside the path. It practically marks the most western limit of the basalt hills in this region. The path then continues north-west over country intersected by valleys in which basalt is exposed. It would be far more direct for the traveller to leave the path east of Um Zinegia, and cut across in a south-west direction to the Dunkur ford on the Aima.
217·9	135½	Gilmu's village, altitude 740 metres, just north of the Workit stream, in which is exposed a basalt with porphyritic felspar and olivine. The present position of the village is about 5 kilometres north-north-west of Um Zinegia. The path leaves Gilmu's in a south-south-west direction, passing over undulating country of basalt, covered with soil. Abdadi flows west.
224·8	139¾	Path lies alongside a bend of a stream called the Bamboha.
225·0	140	Bamboha, flowing west in a valley about 20 metres deep, is crossed. The path continues southwards.
231·8	144	Ajban stream flowing west. The path continues to descend over undulating country until flat plains flanking the right bank of the Aima are reached.
233·3	145	The Aima. This is the Dinder of the Sudan. It occupies a channel 120 metres wide with steep banks rising at angles of 45° to a height of about 5 metres above its bed, which is formed of basalt shingle, altitude 660 metres. It was only just fordable on June 3, and the water rose later. There were abundant tracks of game but none was seen, probably owing to the presence of plenty of other water. South of the ford, the ground rises by rocky slopes to about 30 metres above the river bank. The market to which the Sudan Government formerly organized traders' expeditions, is said to have been situated near the ford, but there is no trace of it now and no villages exist. The path climbs out of the valley and proceeds south-west over undulating country covered with forest, and a number of khors draining north-west are crossed.

Kilometres.	Miles.	
242·3	150½	Khor.
252·5	157	Khor Damu.
256·0	159½	Khor, altitude 670 metres. This lies in a valley about 50 metres deep below the general level of the country.
259·3	161¼	Khor Abu Gemeiz with a shingle bed 25 metres wide and showing flood marks at heights of 4 metres. Early in June there was no sign of "fly." This is said to exist towards the end of the rains, and to infest the neighbourhood of the khors during the early part of the dry season. There was water in pools in March and a small stream in June. There is good grazing. The path continues over flat country covered with forest.
267·6	166¼	North-east corner of Abba Mendi Hill, the path skirts the foot of the rocks to the north-west corner, where the village is situated among the boulders of the lower part of the hill. The people are Hamegs and obtain water from wells. At the village, the path runs to the north-west and descends gently.
274·7	170¾	Khor Melmel flows west over a bed of acid, banded gneiss with foliation dipping north-west; there were pools in June. The path continues over undulating country formed of sandy red soil, altitude 650 metres. The khor joins the Abulj.
280·2	174	Khor Abulj with a large stream bed, 20 metres wide and about 20 metres below the level of the country alongside. It was dry in March. Floods appear to rise about 4 metres above the bed. The path continues over red sandy soil with forest and boulders of limestone.
285·3	177¼	Khor Asib, bed 25 metres wide and flood channel 3 metres deep.
287·3	178½	The path meets the Aima or Dinder and follows its bank, altitude 610 metres at a bend. In March there were pools but no flow. There is good grazing and shade.
289·9	180¼	Another bend of the Dinder. There is no water for a long way to the west of this point. The path ascends to the west out of the valley and continues over country with a distinct slope to the north, as if the Dinder valley is in close proximity.
304·7	189¼	Khor Anki has a sandy bed 40 metres wide showing flood marks at heights of about 3 metres. The channel is flanked by alluvial flats. There were pools in the bed in March. Grazing and shade good. There are some rocks in the bed. To the west the sandy soil continues but the surface is more even with only a few small khors.

Kilometres	Miles.	
312·0	194	Khor Abu Hugar with a sandy bed 80 metres to 100 metres wide, showing flood marks 2 metres above it. Early in June there was no trace of water yet having flowed. Water was found by digging. A well alongside would certainly yield water probably all the year round but would have to be lined. The khor is flanked by low swampy ground with *kuk* trees and *dom* palms. The path continues over red sandy soil with some small shallow valleys, altitude about 600 metres. The going is good. There is a little vein quartz on the surface.
318·4	197¾	Small stream with water from recent rains in June, altitude 630 metres.
320·9	199½	Khor with bed 4 metres wide containing water.
321·4	199¾	Rise among Abu Nesag Hills.
322·6	200½	Khor with bed about 5 metres wide showing flood marks 2 metres above the bed. There are a few bamboos near this khor.
324·3	201½	Khor Babhir, 40 metres wide with rise of 3 metres, flows north-east. It contained pools of dirty water as a result of recent rain. It was dry in March. Altitude 610 metres.
325·9	202½	Stream in small deep channel with rocky sides.
328·3	204	Small outcrops of acid gneiss, and west of this there is rough ground with dark soil. Small stream with bed about 3 metres wide.
330·7	205½	Small stream bed, path continues over red soil.
337·8	210	Khor Abu Ramla, with sandy bed about 100 metres wide with low banks. Water appears to rise only about half a metre in flood. Water is obtained from wells about 1½ metres deep in the bed. There is no doubt that other *gammams* could very easily be dug, and ample supplies could be obtained, especially if cylinders were sunk to hold up the sides and allow the water to be baled from. The path turns south-west.
339·7	211	Base of Jebel Abu Ramla, altitude 640 metres. There were villages at several points around the lower slopes of the hill and the Mek resides near the north-east corner. Water is obtained from K. Abu Ramla, but the supply from the existing wells only suffices the needs of the inhabitants and as soon as it was seen that the party included fifty mules, the way was led to Surrur, a distance of 6½ kilometres to the north, where another water supply exists. Altitude 600 metres. This corresponds in position with the marsh marked on the survey map. There is actually a shallow winding stream with a muddy bed about 15 metres wide and 2 metres deep said to yield water all the year round. There was a shallow well and also

Kilometres.	Miles.	
		standing water, and the fact that these existed in June suggests that the supply can always be relied on. Coming to Surrur involves a detour of about 6½ kilometres each way from the main track, and 13 kilometres is certainly to be avoided if possible. Travellers knowing this would probably do best to camp alongside Khor Abu Ramla, and, if their party is large, the men should dig a fresh *gammam* to meet requirements without encroaching on supplies belonging to the inhabitants.
		Returning from Surrur to the base of J. Abu Ramla the main track is joined running in a westerly direction along the northern foot of the hill;
345·7	214¾	Path leaves hill.
347·7	216	Khor Muhar, with a sandy bed 30 metres wide, flood marks 3 metres high, dry in March. Black soil is reached at about 4 kilometres from Abu Ramla.
352·7	219¼	The small hills of Wiz Wiz are reached.
353·0	219½	Summit of rise among the hills, red soil extends for a short distance to the north. About 3 kilometres farther on, the track passes on to brown soil with a rather cracked surface but making fair going.
373·5	232	J. Mikkin. There is a considerable rise over a belt of sandy soil from the plain up to the base of the hill, altitude 580 metres. Supplies of water are contained in rock cisterns, *galta* (plural *gulud*), but they are difficult to find. At Abu Ramla it was asserted that abundant water would be found and a guide from there led us to an almost dry hole on the north-west side of the main hill. However, one of the men discovered *galtas* close by with ample water for the party and the fifty mules. It is evident that these rock *galtas* are filled by the rains and are exhausted very soon afterwards. There is a small rocky hill on the south of the path, and on the south-west side of this is another and larger *galta* partly filled with mud. It is said that a little water can be obtained from the mud at any season of the year. It is evident that this could not be relied on. The extent of sandy soil near the hill suggests that conditions suitable for wells exist. A trial might be made on the khor on the north-west side and about 200 metres or 300 metres distant from the base.
		The path continues west over sandy soil for a kilometre and beyond this over *badob*.
379·4	235¾	Khor Tab with clay bed, channel 10×2 metres. There was a little water in March. Surface undulates slightly, but there is nothing to justify the topography shown on the survey map. Altitude 540 metres. Path continues over soil.

Kilometres	Miles.	
393·2	244¼	Outlying hill of J. Gerri. The soil comes right up to it.
395·4	245¾	Village of Sheikh Mohammad on the north-east side of the hill. The path turns to the north-west and skirts the base of the hill to the northern corner. It is very stony in places. There is some red soil near Sheikh Mohammad's village, but on the northern side of the hill the soil slopes about 30 metres above the surrounding plain and affords good views over the country. There is little prospect of obtaining water on the eastern side, where the cracked soil reaches up to the base of the hill, but to the north and west, where there are slopes of red soil, the conditions are more favourable for obtaining water. The soil, however, is not sandy. The path leaves the hill and descends over the slopes of red sandy soil towards the west.
402·8	250¼	Village. This is situated on a group of mounds some distance due north of the south-west spur of Gerri Hill. In a hollow, altitude 530 metres, west of the village is the well, brick lined, and about 16 metres to water level. The quality of the water is good with only a slight suspicion of a saline taste and the supply was ample for ordinary drinking purposes. It was not used in June for watering the mules. In March it proved insufficient for 200 mules and the more the animals drank the more they wanted. This was probably due to the difference between the well and river water. The path continues over *badob* soil with a much cracked and rather uneven surface.
412·8	256½	*Hafirs*, or water tanks, with three *tebeldi* trees. The *badob* continues to this point and the path beyond is over red sandy soil, which extends for a distance of about 4 kilometres west of the *hafirs*. *Badob* is then reached.
420·8	261½	Country with shallow valleys and cultivation on *badob* soil. Sandy soil begins and this extends to the bank of the Nile.
421·8	262	View of Roseires.
431·0	267¾	River bank near gauge 455 metres above sea-level.

BAHRDAR GIORGIS TO KHOR ABU GEMEIZ *via* DANGILA.

(March 1921.)

0·0	0	Bahrdar Giorgis, altitude 1,840 metres, latitude 11° 35′ 7″ north. General direction south-west to Ibaba Yesus, good going, little scrub and few boulders.
9·0	5½	Passed through village of Inessa, track turns south along a low ridge, going still good to small stream, Dudu Wanz, tributary of the Imfraz.

Kilometres.	Miles.	
14·0	8¾	General direction south-west, gentle rise all the way; track runs through numerous patches of rock and past a considerable area of cultivated land bordered by thin bush to—
27·0	16¾	Small dry stream, Asabla Wanz, tributary of the Little Abbai.
31·5	19½	Kotkotima Hill, track passes along western side and then bears west-south-west across gently rising grass plain, leaving a large marsh (head of Barud Wanz) on the left.
34·0	21¼	Crossed Barud Wanz which contained running water ankle deep. At the ford the banks were good and the bed pebbly. It is said that this stream is never dry.
41·0	25½	Direction now due west across undulating grass plain.
42·5	26½	Adsum and Injabara Hills now visible in the south-west.
49·0	30½	Crossed the Little Abbai, altitude 2,050 metres, at its junction with Kwoga Wanz, the latter a mere trickle. Below the junction, the Abbai is about 40 metres wide and was nowhere more than 50 centimetres deep; a discharge taken by floats gave about 5 cubic metres a second.
51·0	31¾	Dibukan, a small hill on the west bank of the Abbai. Track now runs over undulating country, thinly wooded with scrub and small trees and intersected by many small streams.
71·5	44½	Dangila market, altitude 2,180 metres, latitude 11° 15′ 50″ north (market day is Monday). At Dangila the caravan which previously numbered 50 mules was increased to 200. Owing to the non-arrival of Ras Hailu's representative, the party was delayed here for seventeen days, after which, with the assistance of Negadras Zelleka, another start was made. General direction west-north-west over undulating grass plain to—
91·0	56½	Kilti Wanz. This stream, which cannot be forded in flood, had 30 centimetres depth of water at the time of crossing. The bed is covered with large boulders which make the ford difficult. The track now rises to Abadra church, then skirts along the hill side and descends to—
93·0	57¾	Mint, a large marsh.
95·0	59	Gagi Wanz. This stream, which is about 10 metres wide with steep banks, contained running water. Track now runs up hill to the village of Tumha, the headquarters of Fitaurari Zelleka. There is no view from Tumha to the west, and the track, leaving the church on the left, descends
99·0	61½	to a rocky stream bed with steep thickly wooded banks and water in pools.

Kilometres	Miles.	
104·0	64¾	Track now bears due west and reaches the edge of the plateau at Daflit, altitude 2,210 metres. There is a magnificent view westwards from this point over the Abyssinian lowlands, a mass of thickly wooded low hills with the mountain Belaiya a conspicuous landmark. The seal of Negadras Zelleka procured a passage through the customs post and the descent was begun at once. The path is very steep and at first only a narrow cutting through the cliff. The mules were obliged to proceed in single file. It then comes out on to the spur about five metres wide with a sheer fall on both sides. There is no improvement as we descend, large loose boulders being strewn everywhere. There are several passes just wide enough to take a mule and almost tunnel-like in appearance. Occasionally the road emerges on to the spur, where the rock is at least earth covered and there is grass and some bamboo, but there is always a sheer fall on at least one side. This steep gradient continues until eight hundred metres from the bottom, where it becomes possible to ride and possible even for wheel transport. (Time of descent, two hours.)
109·0	67¾	Track now runs through small trees and high grass with occasional patches of bamboo to—
111·0	69	Okasha Wanz, altitude 1,450 metres, where there is a good supply of water.
116·0	72	Barabur Wanz, a rocky stream bed with plenty of running water. Track continues through high grass with occasional patches of bamboo but very level all the way.
122·0	75¾	Ali Wanz, a fine stream with running water, banks lined with tall trees. Thick smoke haze, country dotted with small trees, everywhere greenery. Track now runs through thickly wooded country with little grass and cracked cotton soil.
126·0	78¼	Asara Wanz.
129·0	80¼	Kwanti Wanz, a rocky stream bed with running water.
136·0	84½	Sela Sela Wanz, water in pools.
141·0	87½	River Balas, altitude 1,210 metres, latitude 11° 24′ 23″ north, running water and many large and deep pools. This river certainly always contains water. It is at least 8 metres deep in flood and 120 metres wide. There is good grazing on the west bank. The track to Gubba *via* Belaiya branches here from that to Abba Mendi *via* Bagilti. Both guides and *negadis* did their utmost to persuade me to abandon my intention of travelling *via* Abba Mendi, maintaining that the water supply was insufficient to Mendi and that there was none at all beyond. On my refusal half the *negadis* mutinied and threatened the guides, but things quietened down during the night and a start was made at daylight as

Kilometres.	Miles.	
		usual. Track now runs through high grass to a small rocky stream bed, then over cracked cotton soil (slow going) past the—
145·0	90	Church of Arancha Dabr.
150·0	93½	Water in a narrow stream and good grazing on the banks. The country in front is now a tangle of low, thickly wooded hills with Belaiya a conspicuous landmark.
156·0	97	Rocky stream bed with a little water.
160·0	99½	Yakurt Wanz, altitude 1,080 metres. The descent to the Yakurt Wanz is very steep with the usual loose boulders strewn everywhere. This is a very big stream bed and must, by appearances, contain water in many places. A sufficient supply was found in two pools, and it is probable that water can always be got here by digging. Track now bears due north along the stream bed, stony ground alternates with high grass. It is rough even for mules. There is an outcrop of sandstone here.
165·0	102½	Stream with running water in abundance.
172·0	107	Crossed track from Samtai to Wogulda (Alafa district probably).
173·0	107½	Diwall, a rocky ridge.
174·0	108	Rocky stream bed with water in abundance. Track is now very faint and difficult to follow; all visible country is broken by low wooded hills and cut by numerous streams from Belaiya. The ground is everywhere very rough.
180·0	111¾	The track now passes through a natural gateway in the hills, altitude 970 metres. This appears to be the boundary of Ras Hailu's territory.
186·0	115½	Stream with a little water, which was finished before we left. Track now bears west-north-west and the Bagilti and Dangwur Mountains become visible. The country is thickly wooded and there is a succession of dry sandy stream beds.
196·0	121¾	Winza Wanz, plentiful supply of water in pools.
204·0	126¾	Stream with a little water.
207·0	128¾	Left the track, which turns due north towards Dunkur at this point, continued in a west-north-west direction across trackless country, which becomes more parched as we proceed.

Kilometres.	Miles.	
210·0	130½	Khor Abdel Bok, altitude 730 metres, latitude 11° 47′ 33″ north. This is a very big khor with steep banks, the descent being difficult even for mules. There was abundance of water in pools fifty centimetres deep.
212·0	131¾	Khor Jigra, a large rocky khor with water in pools.
216·0	134¼	Crossed the sill of a waterfall in a large rocky khor with a little water. Route now runs through densely wooded, parched country, cut by numerous dry sandy khors. Between successive khors there is often a plateau of anything up to one and a half miles in width with cracked cotton soil. The going is very slow.
224·0	139¼	Khor with a little water.
227·0	141	Small khor with running water and fair grazing. General direction now due west.
236·0	146¾	Abba Mendi is now visible.
239·0	148½	Khor Damu, a large rocky khor with abundance of water in pools. The banks are densely wooded but there was no shade. Route now through dense bush to the—
250·0	155¼	Abba Mendi-Dunkur track. From this point the going is good, the track being evidently considerably used and the country much more open.
252·0	156½	Khor Abu Gemeiz, altitude 660 metres. There was plenty of water in pools, good grazing and no fly. The route from this point to Abu Ramla and Roseires is described in the route to Roseires *via* Alafa. The water supplies at this time of the year west of Khor Abu Gemeiz are as follows :—
281	174½	River Dinder, abundance of water in pools.
297·0	184½	Khor Anki, water in pools.
305·0	189½	Khor Abu Hugar, water can be obtained by digging.
339·0	210½	Pool, 6 kilometres north of Jebel Abu Ramla.
401·0	249¼	Gerri well.
429·0	266½	Roseires.

GENEARL DESCRIPTION OF THE COUNTRY BETWEEN BAHRDAR GIORGIS AND ROSEIRES.

The vesicular basalt of the Bahrdar Giorgis lava type extends as far as the Little Abbai, where the ford is situated at a rapid formed by a bar of the rock. Similar rock is met with for a mile or two on the west side of the Abbai and it seems as if this lava must

be the result of an eruption from a centre not far north of Rim and from which the lava has flowed northwards into the hollow now occupied by the lake and has also rounded the spur of older rocks and filled the Blue Nile valley at least as far as the first bridge.

The Little Abbai occupies a wide open valley, and, where it was met with, is flanked by alluvium. There are well marked berms which separate the channel from low lying, swampy areas alongside, sometimes with papyrus. Where the stream is flanked by alluvium, it is about 70 metres wide, such as appears in Photograph 33. At the ford, where there is a rock bar, the stream contains some small islands and is about 100 metres wide. The river bed here proved to be rock and not sand, but there were layers of basaltic sand in the alluvium of the islands and banks. The discharge on May 25, 1921, was certainly about 4 or 5 cubic metres a second or nearly as much as the whole discharge at the outlet of the lake. The flat nature of a large extent of its catchment area can be seen from the east slopes of the valley and it is only necessary to look around in the month of May, just before the rains begin in earnest, to realize how parched most of it can be. The soil is fissured with deep wide cracks requiring much rain to fill them. The country between the hills west of the Abbai is also of deeply cracked soil from which there can be very little run-off until the ground becomes sodden. It supports a marsh vegetation which in its turn doubtless absorbs a large proportion not only of the direct rainfall but also of the water running down the neighbouring slopes. The region between the ford and Assiru Dabr is formed of recent volcanic rock associated with much scoria and many of the little hills rising abruptly above their surroundings obviously are volcanic cones.

The lowness of the country to the west of the lake between Assiru Dabr and Gabgabit is rather remarkable and most of the prominent hills on it are isolated volcanic cones which are clearly quite recent additions to the landscape. This topography accounts for the absence of any notable streams.

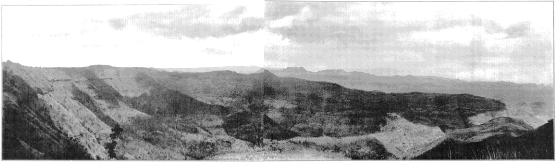
From Forohe there is a good view of the Abbai Ras. The river has built out a narrow tongue stretching a long way into the lake. Towards the north the tongue forks, but Major Powell Cotton, (1) who visited the mouth in May 1900, describes the river as entering the lake in a single stream after dividing and passing round an island.

The shore of the lake is low as far north as Dengelbar. At this point there is a bay containing some marsh and flanked by hills both south and north. It clearly represents drowned topography only partly silted up. North of Dengelbar, the lake washes up against hills and the country inland to the west rises perhaps to 400 metres above the level of the lake, being higher than that to the south.

There are volcanic cones as far north as Gabgabit, but it seems as if Dengelbar may be mentioned as the northern limit of this recent volcanic field.

North of Gabgabit the watershed is within about 5 kilometres of the lake shore, and a small hill, altitude 2,250 metres, affords fine views over the edge of the high plateau. There is no defined scarp and the present limit of the high country is evidently due to erosion. Just to the west of the watershed there are well defined water courses with very steep falls, and the valleys beyond wind among spurs carved in horizontally bedded rocks. The high country can hardly be referred to as a plateau, as its surface is by no means flat. Beginning at the south, in the distance can be seen the northern and western slopes of Mara or Wagera Mountains, and beyond them the high land terminates in a sharp headland. North of the mountains, the escarpment is lower and there is an almost flat

(1) "Sporting Trip through Abyssinia," London 1902, p. 276.



No. 34—The Escarpment West of Alafa.

region west of the mouth of the Little Abbai. North of this the ground rises to the Alafa plateau situated north-west of Dengelbar and where the high land extends westwards for several kilometres west of the general line of the escarpment to the south. The surface of this plateau appears to be level with the summit of the hill on which we are standing or about 400 metres above the lake. The region west of Assiru Dabr promises best for the route of either a railway or a road and clearly deserves to be examined. At that point there is hardly any fall from the edge of the plateau to the lake, while both to the north and to the south routes would have to climb up over ridges and descend again.

The hills on the plateau immediately west of Dengelbar do not display obvious signs of plateau structure. In fact their outlines sometimes suggest inclined beds. The dominant rock in this region is a basalt with large crystals of augite, and it is seen, in streams and in exposures on hillsides, to be compact and irregularly jointed. Possibly it is either an intrusion or an unusually thick bed. To the north, at Alafa, the plateau rock is compact basalt without conspicuous crystals. The vegetation at Alafa is characteristic of its level, and includes hypericums, olives, and roses, but the dominant tree is the ubiquitous *girrar* acacia. There had evidently been rain early in May, as the grass was already pleasantly green, in contrast to the dry country traversed near the lake. Cultivation had begun, and people had already made their carefully tended and protected seedling beds of red pepper.

There is said to be a hot spring near Dengelbar and another below the west edge of the Alafa plateau. The former could not derive its water supply directly from seepage of the lake water, consequently it must be associated with the recent volcanic action.

The site of Chara Giorgis church, said to have been destroyed by the Dervishes, is on the left of the path on the western edge of the Alafa plateau. It is marked by a group of trees on a small hill rising above the general level of the plain. West of the church is the edge of the plateau, and a small knoll on it commands views around. To the south are the Mara or Debrasina and the Wagera or Dakona Mountains which form the edge of the high land north of Dangila. The most western limit of these is marked by an abrupt cliff, but for the most part the hills slope steeply down towards the west. The view of the country below Debrasina is cut off by a ridge at a distance of about 5 kilometres to the south, culminating towards the east in a flat-topped, barren looking ridge with the church of Saba Medahni Alam. This ridge may be regarded as a spur from the southern part of the Alafa plateau, with which it is connected by a neck of rather lower ground, also said to be inhabited. The ridge extends a long way to the west. Beyond it can be seen a defined peak, perhaps about 16 kilometres distant, said to be Shimala Johi. In the distance to the south-west could be seen the plateau mass of Belaiya, and beyond it Dangwur is visible, but is too far away for its structure to be discerned. Below Chara Giorgis and the knoll from which the country was viewed, the ground falls abruptly for about 300 metres in regular cliffs, at the foot of which are valleys separated by ridges, all carved from horizontally bedded volcanic rocks. A group of hot springs where the water is stated to be very hot and effective is said to be situated about 2 kilometres to the west but perhaps 500 metres below the edge of the plateau. These various tributaries unite into the Sidd, which afterwards joins the Dinder. Photograph 34 may serve to give an idea of the part of the view already described, looking southwards and south-westwards from the knoll on the edge of the plateau west of Chara Giorgis church.

The foot-hills of the scarp extend perhaps 8 or 10 kilometres to the west and then merge into a plain which extends westwards to a range of hills above which rise the

Bafa Hills of the survey map, the highest of which was stated to be Bujarr. Beyond these to the south could be seen the Bagilti Hills, the Abuggalita Hills of the map, with many irregular peaks. To the north of the Bafa Hills and nearer, is the Bardanki plateau, rising slightly above the plain, and beyond it is seen a gap suggestive of the position of a river valley lying between the Bafa Hills on the south and the Kwara Mountains on the north. These mountains include two peaks in a direction rather north of west from Chara Giorgis, and north of these is the high plateau of Kwara, which extends some distance and is flanked on the east by the plain separating it from the main mass of the Abyssinian highlands.

The view to the north was cut off by a spur about three kilometres away. This spur, which is to the west of the road, commands views of the country northwards and hills are seen on the Sudan frontier just south of Gallabat. Hills south-east of Gallabat on the road to the plateau can also be recognized. None of these are high and they are to be regarded only as irregularities in the general slope of the ground from the foot of the high land down to the plain.

The topography combined with the horizontally bedded structure, which is well displayed on the hill-sides, makes it clear that there is no tectonic feature associated with the edge of the high land. A further point in support of this view is the irregularity of the escarpment at Alafa, where the high land stretches westwards beyond the general line. The horizontally bedded structure can be followed on the ridges of the foot-hills as well as on the low plateaux rising above the plain, and extends to the Kwara mass, which was observed subsequently from the road. Belaiya was too far off for its structure to be recognized, but its outlines, as well as those of Dangwur, leave little room for doubt that they arise from a horizontally bedded structure. These masses are all to be regarded as outliers of the Abyssinian plateau and there can be no question that the scarp which forms the western edge of the high land is simply a result of ordinary subaerial erosion.

The traverses made by the Tana Mission have enabled the position of the edge of the escarpment to be defined south of the ascents on the routes from Gallabat to Chilga and Delgi where it was already known. It has been found to include the Alafa plateau, south of which there is an embayment and the escarpment approaches nearest to Lake Tana at Gabgabit. Beyond this it pursues its direction almost due southward with the Mountains of Mara or Debrasina and Wagera or Dakona rising on its edge, and cuts off the hills west of Injabara in what appear from the distance to be tremendous cliffs. It is known that the country south of the basin of the Little Abbai falls considerably, so that the escarpment south of the Injabara Hills must be lower than to the north. The feature, however, seems to continue, forming the western boundary of the Damot district. The views of travellers following a river bed are always restricted by the sloping sides of the valley, but it may be gathered from Jessen's (1) descriptions that the Blue Nile leaves the high hills just west of Damot and traverses relatively low country beyond. This separates the basaltic highlands of Abyssinia from the granitic and gneissose hills of Gubba, through which the river enters the Sudan.

The country near the edge of the escarpment is formed of basalt with a covering of red soil bearing *girrar* acacias, many eugenias and shrubs with umbel-like groups of tubular yellow flowers. Near Fingeta Abbo Church, at an altitude of 1,780 metres, the

(1) "W. N. MacMillan's Expeditions and Big Game Hunting in Southern Abyssinia and East Africa," by B. H. Jessen, privately printed, London 1906, but sold off recently, p. 316.

vegetation includes large proportions of eugenias and gardenias, combretums, and some proteas. The *talh* acacia was first met with at the end of a steep descent that begins a little way beyond the church. *Commiphora pedunculata*, Ar. *luban*, trees were first found about halfway down and gardenias and combretums continue down to the foot of the steep part. The whole descent is over a series of horizontal basalt sheets, possibly with beds of tuff or ash among them. The hard central portions of the basalts have given rise to the steepest parts of the descent. Each bed of basalt differs slightly from its neighbours either in texture or in composition. The second from the top of the series is a fine grained rock, compact and almost flinty in texture. It is rudely jointed into vertical columns, and this makes bad going where the path has to descend across its face. Below it there is a little shelf formed by the surface of the third bed of basalt. A rather coarse grained type has weathered into the boulders met with on the path below 1,850 metres altitude. Near Fingeta Abbo there is prophyritic basalt. The hot spring rises just south of the stream at the foot of the descent in a little marshy spot, where people have made a covered bathing place. The temperature of the water is 39° C. There is a very slight sulphurous smell but nothing else to indicate that the water is mineralized.

In the dry season, when grass becomes scarce at Alafa, the people send their cattle down to some shelf, part way down, or right to the base of the descent, to graze there until the early rains bring fresh grass on the plateau.

The progress from the camp at the foot of the slope was marred by the presence of several guides who each advocated and led sections of the party by different ways. It brought home the fact that here, as in many other parts of Africa, villages are frequently moved so that fresh ground may be cultivated. A branch is then made from the old path to the new site, and often the most beaten track lies from one cultivated patch to another. A guide acquainted with affairs a few seasons before may be completely mazed by the new arrangements, though he is still of value if he remembers the general direction.

Near the place where the River Sidd is first crossed, the country is covered with small trees, including *khash khash*, *Stereospermum kunthianum*; *luban*, a few acacias, etc. There are also debris of many bamboos but very few living, and these are small, as if they are seedlings. It is said that all this country and much to the west was formerly densely covered with bamboos, so that the paths among them were dark, but they have been attacked by a "worm" and practically wiped out. This seems to have happened in quite recent times, as Mr. C. H. Walker, who traversed the region in 1906, records cutting a path through the bamboos on the route south-east of Dunkur, and Major Powell Cotton, who visited the low country north-west of Dangila in the spring of 1900, describes the great stretches of bamboo which appeared like green grass viewed from the top of the escarpment. The recent change in the character of the vegetation is borne out by the uniform size and comparative youth of the *luban* trees, which seem to have replaced the bamboo, and now cover vast stretches between the foot of the escarpment and Dunkur.

At the second crossing of the Sidd the rock forming the bed is a highly amygdaloidal basalt, almost certainly representing a surface flow of lava. Zeolites, generally radial aggregates of acicular crystals of the natrolite-thompsonite group, and chalcedony, become conspicuous on the surface of the ground west of the foot of the main descent. They are practically absent above, and this suggests a distinction between the basalt lavas of the upper and lower parts of the series, since, at Gallabat, where similar rocks also occur, they are characterized by abundance of zeolites. Zeolites and chalcedony are minerals that have formed in the steam cavities of the lavas during the process of cooling. They are

more stable than their parent rocks and consequently remain after their matrix has rotted and become soil; the result is that the surface of the ground is strewn with pieces of these minerals, which are conspicuous by their whiteness.

The path lies in a valley between spurs from the scarp; towards the west this widens, the spurs decrease in size and terminate on what appeared to be a plain as seen from the top of the escarpment. Experience shows, however, that the surface is quite rough, with undulations between many stream beds that drain southwards towards the Sidd. It is covered with small wood, 5 to 7 metres high and consisting principally of *luban* and *leyun*, *Odina fruticosa*, with a few bamboos, and these contribute to obscure the broken character of the surface. Much work and many bridges would be required to prepare a road good enough for mechanical transport.

The "plain" or lower plateau is bounded on the north by a line of hills which extends to Kwara and separates the drainage of the Sidd from that of the Shimfa, in fact the Dinder basin from that of the Rahad, as the respective rivers are known in the Sudan. The dividing line is a continuation of the ridge on which stands Fingeta Abbo Church, noted during the descent from the plateau. The Bangun on the north side of that ridge drains into the Shimfa.

On the path between the streams there are occasionally patches of cracked black soil, and some of these near the foot of the escarpment are cultivated. This soil is very similar in appearance and character to the *badob* or black cotton soil of the Sudan, yet it appears to be quite distinct in origin. It is certainly of basaltic origin and it has been observed even on the highlands of Abyssinia where the soil is sedentary. Its natural red colour has been lost by the development of humus, which makes it black and doubtless also imparts physical properties such as that which enables it to absorb large quantities of water and to dry subsequently with the formation of large cracks. The red soil does not crack to the same extent. Both kinds of the black soil contain kankar lime nodules but possibly careful analysis might show a distinction between the basaltic soil and the loess *badob*. They cannot be distinguished by inspection in the field.

The country continues to be formed of bedded basalts and these are displayed on the sides of the Bardanki plateau, which rises at a little distance south of the path and shows a dip of about ½° towards the west. A similar dip in the same direction was seen farther on, in the Bafa Hills. In the neighbourhood of Gumoha the rock contains chalcedony and zeolites, including natrolite and stilbite.

A heavy rainstorm occurred in the afternoon while the party was camped alongside the Sidd, which caused torrents to pour down a number of small tributaries, and raised the level of the main stream. After a couple of hours it had fallen considerably, thus showing the localness of the rain. Next morning it was down almost at its previous level. The country near the escarpment had evidently already had a certain amount of rain, but before reaching Umbibal's (Umbiilal's), a district with hardly any green grass had been crossed, showing that almost no rain had fallen on it. The western margin of this area was reached about 1½ kilometres east of Umbibal's, where another belt of fresh green grass was entered. The vegetation to the west includes a few *talh*, some baobabs, ebony, *Dalbergia melanoxylon*, and *tartur*, *Sterculia cinerea*, but consists principally of combretums and *luban*. Towards the Aima ford, south of Gilmu's, there are sausage trees, Kigelia; combretums are represented by Terminalia, Ar. *darot*, *Anogeissus leiocarpus*, Ar. *silg*. *Ximenia americana*, Am. *inkwoi*, a small tree with yellow fruit resembling little plums, common near Bahrdar Giorgis, is met with as far as Umbibal's country.

The route has lain a little way north of the Sidd river. In Umbibal's country, this is said to join the Aima coming from the south-east. The Aima is regarded as the larger river, but its valley above the junction was not recognized from the route traversed. The united stream continues to be called the Aima, and the name Dinder, by which it is known in the Sudan, is unknown here. The prominent little hill of Um Zinegia marks almost the western limit of the basalt hills. The valley of the Sidd opens out west of Umbibal's villages, and the hills on its southern side do not extend as far as those on the north. The basalt underlies the plain for some distance west of the hills, and is met with in stream beds. These bedded basalts certainly represent the same series as those of the Abyssinian highlands, which must have extended almost to this point. That it did so, and that there was a great thickness of bedded basalts within a short distance of the edge, is proved by the presence of the Kwara, Belaiya and Dangwur outliers. Basalt rock is exposed in the bed of the Aima at the ford. There is a little recent alluvium forming narrow shelves alongside the channel, and on rocky slopes on the south there are banks of a coarse shingle representing older alluvial deposits.

The path south of the ford turns south-west over country with soil resting on basalt, which is seen in stream beds. About 6½ kilometres from the ford, the basalt is left and a pink or reddish mudstone is met with. This might be easily mistaken for rotten basalt but its exposures are too extensive. About 3½ kilometres farther on, sandstone is well exposed in a valley and to the south-west it forms quite rough country traversed by deep valleys. A tributary of Khor Abu Gemeiz lies in a valley nearly 50 metres deep below the general level of the country, with steep rocky sides of sandstone. The soil on the sandstone is generally red and sandy and travelling over it was possible, even while heavy rain was falling. Mr. Black states that he met with sandstone west of Khor Yakurt on the track east-south-east from Khor Abu Gemeiz. The number of khors along this part of the route and especially the deep ones form very serious obstacles to the making of a road for mechanical transport. Possibly some might be avoided by a route lying farther away from the Aima but several are large and doubtless have long courses. The vegetation includes *silg* and some trees that are suggestive of Butyrospermum but have spikes of flowers. A curious little herb, Dorstenia, with white, leaf-shaped flowers about 4 inches high is abundant near here. The first *Balanites Aegyptiaca,* Ar. *heglik,* was seen near Khor Abu Gemeiz.

A little way south-west of the tributary, the sandstone thins and overlies fine grained muscovite biotite gneiss with foliation dipping north-west. It is associated with hornblendic bands and quartz veins. About half a kilometre north-east of Khor Abu Gemeiz there is a band of limestone or dolomite and in the khor itself limestone is associated with garnetiferous, quartz mica gneiss, dipping 45° west. Apart from the rock, the khor has a shingle bed 25 metres wide, showing that the water rises to a height of about 4 metres. There are oyster shells associated with the shingle, and it can be concluded from the presence of these that there are permanent pools in the upper reaches. A bed of limestone about 4 metres thick occurs in the bed of a small khor just beyond, and 100 metres farther west is a bed of white, banded, saccharoidal marble at least 50 metres in thickness. More limestone was met with between Khor Abu Gemeiz and Abba Mendi Hill. This hill proves to be formed of a prophyritic hornblende biotite rock, either red or grey in colour and resembling the granite of Gebelein on the White Nile. It has weathered in large boulders, but at the north-west corner it rises above the village in a solid mass like the hill at Segadi. The soil between Abu Gemeiz and the hill is red and sandy and no *badob* was met with.

Some difficulties in making a route for mechanical transport along the line of this part of the track have already been noted. The most serious of these is the system of channels at Abu Gemeiz which will involve bridges or long cuts. There is also a good deal of rough ground near Abba Mendi but this might be avoided by giving the hill a wide berth. The best route in this region is probably situated along the watershed between the Aima and the Blue Nile, but farther east the line would have to cross the Aima, and continuing eastwards at the foot of the slopes of Kwara, there would be considerable difficulties in getting good gradients where the Sidd passes through between Kwara and the Bafa Hills. Farther east, a railway line would have to travel along the slopes of the ridge that connects Kwara with the highlands, to gain altitude before reaching the escarpment. It would then turn southwards along the slopes, piercing some spurs with tunnels, and eventually attain the Abyssinian plateau south of Gabgabit. An idea of the very great difficulties in the construction of a railway line that would be met with at the escarpment may be gathered from a study of Photograph 34.

The khors north-west of Abba Mendi expose banded acid gneisses. In one not far from the hill, the foliation dips at 45° to the north-west. About 6 kilometres north-west there is an extensive show, on the surface of the soil, of boulders of what appears to be high calcium limestone. A kilometre beyond, there are outcrops of grey limestone, probably dolomitic in character, and half a kilometre farther on, seven and a half kilometres from the hill, there is a large outcrop of dolomitic limestone. In Khor Asib there are acid gneisses with foliation dipping at 40° to the north-west.

The country rock, at the place where the path meets two bends of the Dinder or Aima, is an acid felspathic gneiss with garnets. Pieces of limestone were met with on the soil south of J. Mogumbi. The river lies in a defined valley about 30 or 40 metres below the surrounding plain. There are several rapids among rocks in the river bed, and in the intervals there are banks of shingle. The rocks in the river bed are blackened and this was also seen in Khors Abu Gemeiz, Abulj, and Asib. Good views were obtained from J. Mogumbi, a small hill that rises on the edge of the valley about 6 kilometres north-west of the point where the Abu Ramla path leaves the river. The country is seen to be formed by a plain, above which rise towards the east, Kwara, Bafa, Bagilti, Abba Mendi, Belaiya and Dangwur. To the west and south-west is the range of hills extending from Abu Ramla to Gubba, and this is quite distinct, being separated by a wide stretch of plain from Dangwur, etc., to the east. The view gives the impression of a plain extending from Gubba range to Abba Mendi. It is, however, well wooded and irregularities are covered and may be masked. Experience along the track has shown that, at any rate towards the Dinder, the plain is cut by a number of valleys and the appearance of flatness is deceptive. The views of Dangwur have always been too distant to allow its structure to be discerned, but it is almost certainly formed of bedded basalts. This conclusion is supported by its height and by its proximity to the Belaiya mass. The outline of the Bagilti Hills is rough and irregular and they may be granitic, in fact an inlier among the plateau basalts.

West of the point where the Dinder is left, the path is over red sandy soil with outcrops of acid gneiss. Khors Anki and Abu Hugar are both large with wide sandy beds in channels flanked by alluvium. About 8 kilometres west of Khor Abu Hugar the path ascends a rise of acid gneiss with foliation dipping 40° to the north-west; there are granitic hills in the neighbourhood. About a kilometre farther on, hornblende gneiss with foliation dipping at 80° to the north-west was met with. There is acid gneiss with vertical foliation striking north and south in Khor Babhir and similar rock is met at

two other khors beyond. Farther on, dark soil occurs and extends to within about 5 kilometres of Abu Ramla, whence red sandy soil stretches to the base of the hill.

J. Abu Ramla proves to be formed of syenite, similar in character to that of Fau and J. Geili in the Sudan. There is a gentle slope towards the north from the base of the hill over sandy soil. Black soil is met with about 1½ kilometres from the hill and continues to Surrur, where it proves to be underlain by sand, which provides the permanent supply of water in the khor bed. Possibly the water in the sand may be fed from the slopes around the hill. The occurrence of black soil a little distance east of J. Abu Ramla has already been mentioned. It was again met with at the foot of the slope north of the hill and it appears as if this can be regarded as the eastern limit of the *badob* of the Sudan.

The hills of Wiz-Wiz are of granite and acid gneiss with pegmatites. After a space of red sandy soil near Wiz-Wiz, cracked brown soil extends to near J. Mikkin, which is bordered by slopes of sandy soil and is formed of an even-grained granite. There are small outcrops of acid gneisses on the south, and these doubtless represent the country rocks among which the granite of the hill has been introduced.

Cracked *badob* soil extends nearly all the way to J. Gerri, where the surface is flat right to the base of the outlying hills on the east. The rock of the hill is a lateritized schist with structure almost obliterated. It seems to represent chloritic schist, of which there are traces. Towards the north and west there is a belt of sloping red soil flanking the hill. The soil is red but not sandy. The western village is situated some distance west of the hill and stands on some mounds, where there is rock debris on the surface. Possibly the mounds are due to the presence of rock. The well is situated a little way to the west and there are debris of red lateritized rock and also fragments of other materials, doubtless transported, such as granite and sandstone. There is nothing to indicate in what the well was dug, but the presence of lining shows that the material was soft.

West of the well the path is over *badob* soil with *talh* acacias. Beyond the *hafirs* there is a stretch of sandy soil, possibly representing old dunes, and some undulations on the surface support this view. The sandy soil bears characteristic vegetation : combretums, ebony, etc., but *talh* acacia is met with again as soon as the *badob* soil is reached. The belt of sandy soil of the Nile valley is reached about 1½ kilometres east of Roseires.

The forest can be said to end near J. Mikkin. Open spaces are seen to the north of this and towards J. Gerri there is, as a rule, only a sparse growth of *talh*. On J. Gerri and around its base is a forest of *luban* with bamboos, chiefly towards the west. The latter are small but fairly numerous and this was the only place along the route where the occurred in any quantity. Supplies of them are obtained for use at Roseires and quantities were even being sent to the Red Sea Province.

Mr. Black who traversed the route in March records that from the Dinder to Roseires he travelled principally during the night owing to the long waterless stretches. He utilized the two hours before dark, then halted until the moon rose. Even so, the journey from Abu Ramla to J. Gerri occupied fourteen hours and was finished in the heat of the day. The Tana Mission mules were grain fed throughout the journey and no salt was allowed after leaving Dangila. The hired mules had to rely almost entirely on grazing and all, accustomed to the abundance of water on the Abyssinian plateau, undoubtedly suffered from the shortage between the Dinder and Roseires. With a large convoy of mules the Abu Ramla route should not be attempted at that time of the year.

The remarkable point about the route from Roseires to Bahrdar Giorgis is the great extent of low country stretching nearly 200 kilometres from the foot of the escarpment to the Sudan boundary. Except for the villages at the western fringe of the foot-hills and those at Abba Mendi, Abu Ramla and J. Gerri, it is uninhabited. The people of these villages are negroids of either Hameg or Gumuz tribes, and appear to have suffered considerably from raids in former times. They still live in fear, as was shown at Abba Mendi, where sentries were found posted on the outskirts of the village. One of these came up and asked us to stop a few minutes until the chief had been warned of our approach. There were rumours of the presence of a raiding party and the people were evidently nervous. They have numerous rifles but it was said that most of them have no ammunition. There was considerable difficulty in obtaining guides from these people and those that were sent by their chiefs wanted to return at the earliest possible moment. On one occasion the two of them returned without waiting for their pay and the pair who were sent by Gilmu would not cross the Aima, but as they had their rifles with them they could not have swum and there was certainly a doubt about their being able to get back across the rising river. The region is well supplied with water and there are large stretches of excellent soil, which leave no doubt that great developments are possible. The fertility of the ground is demonstrated by the growth of forest. Abyssinians from the highlands are unlikely to colonize this area, as they dislike the heat and dread fever. They only come down with the object of hunting and if they succeed in killing an elephant this secures them renown for the rest of their lives. A few of these sportsmen were met at J. Abba Mendi. The development of this huge stretch of land must therefore depend first on the establishment of settled conditions, followed either by increases of the present population or immigration.

The scarcity of population reduces the attractiveness of the route. If transport were to be organized along it, camels or light cars would be used from Roseires to Umbibal's country in the neighbourhood of Kwara. Many valleys have to be crossed and explorations would have to be made to find a line that avoids the rough going and difficulties of the present track. The distances between water supplies on this part of the route are not objectionable as regards camels, but the presence of "fly" near some of the khors is a very serious obstacle to the use of animal transport. Motor cars are therefore preferable. A good deal of clearing must be done along the route and wells in favourable places near some of the khors would improve the water supply east of Abu Ramla. A well at Mikkin is most desirable, but the success there is problematic. A depot would have to be formed in Umbibal's district at Kakrwaha, where goods would be reloaded on to mules for transport to the Abyssinian plateau. This is almost as far from Lake Tana as Gallabat, and starting from the nearest point on the Sudan Government railway it is not nearly as convenient to reach. The same objections hold regarding the track branching from Khor Abu Gemeiz to Dangila, though Mr. Black considers that the construction of a rough road by this route for use in the dry season, and capable of taking light, mule-drawn wagons of the British Army G.S. pattern, presents no engineering difficulty except the ascent to the Abyssinian plateau. A considerable amount of labour would be required mostly in clearing boulders, scrub and small trees and making ramps to the banks of khors where necessary. Wagons of such a type could be driven through practically all the streams and the difficulty of those with soft sandy beds might be overcome by carrying a supply of wire netting to make a temporary path. The southern route from Roseires through Gubba to Dangila, though better supplied with water, is much longer. After full consideration it can be stated that the road through Gallabat to Delgi is to be preferred, as a means of reaching Lake Tana, to any route from Roseires.

Regarding the administration of the country along the route from Bahrdar Giorgis in June 1920, Fituarari Amarro controls the country east of the Little Abbai. At Dangila there is Ras Masfan, the husband of Ras Hailu's sister, but he has little real authority and is spied upon by Alaka Luli, a clerk in charge of the market, appointed by Ras Hailu. Negadras Zelleka, too, has his headquarters at Dangila and is in charge of tolls in the neighbourhood.

Fitaurari Makonnen of Achafar controls the country from Dangila to north of Assiru Dabr, and his authority probably extends on to the low land west of the escarpment. North of this, Fit. Dasta controls the district as far as the boundary of Ras Hailu's country at Gabgabit. On the northern side of this boundary Alafa extends westwards and is under Fit. Daboch, who is one of Dedjaz. Ayalewu's subordinates. The north-west of the lake down to near Dengelbar is under Ras Gugsa, so that Dedjaz. Ayalewu has only a short stretch of country bordering the lake. The fact that it exists necessitates possession of a pass from this chief to avoid paying tolls. Leaving the escarpment, the authority of Fit. Daboch of Alafa extends to Kwara, and the Kudkud river is regarded as the boundary of the two districts. The control of the Hameg and Gumuz people between Umbibal's and the Sudan boundary does not seem to be well established and, in June, 1921, awaited a decision of the Central Government. Dedjaz. Banja (Abu Anga) of Gubba is the most important chief in this district and formerly paid tribute to Fit. Zelleka of Belaiya. When Belaiya was added to the territory of Ras Hailu, Dedjaz. Banja refused to continue to pay tribute to Fit. Zelleka and subsequently paid to Dedjaz. Ayalewu. The decision was given in favour of Dedjaz. Ayalewu, and as a result this chief controls all Abyssinia bordering the Sudan boundary north of the Blue Nile, with the exception of a small "corridor" which places the trade routes between Gallabat and the plateau under Ras Gugsa. Ras Hailu's country extends nearly 40 kilometres west of Dangwur to Khor Yazig on the Gubba route, while the boundary between it and Ayalewu's is crossed about midway on the route between the Balas and Khor Abu Gemeiz. The route from Alafa through Dunkur to Abu Ramla lies entirely in Ayalewu's country.

The Route from Gallabat to Delgi.

This route was traversed by Major A. G. Colquhoun, D.S.O., who was in charge of the convoy of stores and equipment for the Tana Mission in 1920. From Gallabat the Chilga road is followed to the Gandoa river, a distance of 40 kilometres, where it diverges and crosses to the right bank of the stream. The Delgi road does not cross the Gandoa. The surface of the ground is formed to a large extent of black, cracked "cotton soil" or *badob* with patches of stony ground. The country rock is basalt, which is seen on the sides of hills and beds of streams. There appears to be an ample water supply during the dry season from pools in streams, especially at the Gandoa.

After the Chilga track branches off, the country becomes more stony, but the route may be regarded as feasible for camel transport up to Geldau Hill, where the watershed between the Atbara and the Rahad is crossed at a distance of about 80 kilometres from Gallabat. Gallabat is 700 metres above sea-level and at Wahni, opposite Geldau, Mr. Buckley found the height to be about 1,100 metres. South-east of Geldau Hill the path rises over rocky ground. In this neighbourhood there are several hot springs and a mineral spring. Mr. Barron, who traversed the route in 1904, remarked that the lowest, down the Jira Wanz at Mwat Abba Mahari, was resorted to by people as a cure for skin

diseases, rheumatism, etc. The water is too hot for a white man to enter with impunity and it is impossible to hold the hand in it for any length of time. There is a bathing pool with three divisions, so that the water passes from one to the other, and is coolest in the outer. There are other hot springs, and one of them is associated with a spring of cold water. The mineral spring is at Ambo, north of the road, about 2 kilometres east of Mwat Abba Mahari, and the water, with quantities of bubbles of gas, issues from a fissure. The bubbles give the appearance of boiling, but the temperature is only about 30° C. The taste is saline, the water is said to be purgative, and cattle come from long distances to drink it. From Ambo the path traverses rough plains to Dilwa, after which begins a very steep ascent to Barbarie Kora on the edge of the escarpment at an altitude of about 2,200 metres above sea-level. From this point there is a gentle descent for a distance of about 12 kilometres to Delgi on the shore of Lake Tana.

It might be practicable to make the route feasible for motor transport as far as Geldau. Beyond this point to the top of the escarpment it would be very difficult, and a road would have to be cut along the faces of the cliffs and steep slopes.

APPENDIX IV.—TRAVEL AND SOJOURN IN ABYSSINIA.

The following remarks are only intended to refer to the parts of Abyssinia traversed by the Tana Mission and should not be regarded as applying in other directions. When Abyssinia is referred to it should be interpreted in this restricted sense and the suggestions for travellers are not to be thought of as holding good throughout the wide areas of many different climates and kinds of people included within the Abyssinian Empire.

Native Personnel.

When travelling in Abyssinia it is useful to have an armed escort which can be used as a guard when a camp is formed. In entering from the Sudan, there is much to be said in favour of selecting reliable Arabs for this purpose, as they are unlikely to desert while in Abyssinia. If Abyssinians can be found who have been long enough in the Sudan to have formed attachments, a proportion of them may be included among the retainers and they will interpret for the men and may be useful sometimes when the official interpreter is not available. Negroes are looked down on by the Abyssinians and that feeling extends to the employer, consequently they should be avoided in selecting both escort and personal servants. Light coloured men may be mistaken for Europeans by the Abyssinians, especially if they are allowed to wear European clothes. If the traveller is fortunate enough to possess a well tried personal servant or a cook, either an Arab or Nubian, who is willing to follow him to Abyssinia, he will not regret taking him. The language may be a little difficulty at first, but if the cook is supplied with an Abyssinian to act as " cook's boy " matters will go smoothly, especially if the latter knows a little Arabic. There never seemed to be any difficulty as regards language with the Arabs who accompanied the Tana Mission in 1920–1921 and it was astonishing how soon they picked up a working knowledge of it. If fresh servants have to be engaged it is probably best to take Arabs or Nubians from the Sudan unless there is assurance of finding well trained Abyssinian servants on the spot.

About thirty Abyssinians were employed continuously by the Tana Mission in 1920–1921. Most of them were engaged at first as mule drivers for the journey from the border, but subsequently they proved very useful in many capacities and the majority were intelligent and willing. Those engaged at Gallabat began with pay at the rate of ten dollars a month and this was increased in some cases to eleven or twelve dollars a month. We were fortunate, too, in having an excellent head-man in Gabra Mariam, who joined us at Addis Abbaba. At Bahrdar Giorgis there were continual applications for work and there was very little doubt that quite a large number of men could be employed at the rate of about ten dollars or less a month.

The Abyssinian interpreter should be tactful as well as a good linguist, since the traveller may have to rely on him for guidance regarding etiquette and all sorts of local procedure. It is difficult to overestimate the value of a really good man in such a position, as business will be facilitated and the stranger may often be saved from giving unintentional offence.

Transport Equipment.

Animals.

Either ponies or mules are ridden in Abyssinia and it is probably most convenient to purchase the animals used for this purpose. A good saddle mule costs from fifty to a hundred dollars and ponies from fifteen to thirty dollars each, but really good animals are not plentiful. Abyssinian donkeys are very small and are never ridden, but mules are the most useful pack animals. If a single definite journey is being made it is probably simplest to arrange a contract with a *negadi* or muleteer for the transport of the baggage at a certain price for loads of given weight. This avoids the necessity of buying animals, pack saddles, and arranging for drivers and forage, but the latter is the more convenient course if a tour of long duration has to be undertaken. Pack mules cost from twenty to thirty-five dollars and an average of about twenty-five dollars may be assumed.

Saddles and Stable Gear.

Riding saddles of ordinary European pattern and fitted with cruppers should be taken for the personal use of members of an expedition. The local kind turn up at the back, have a wooden projection sticking up vertically in front and may be supplied for the use of interpreters and servants.

The Abyssinian pack saddle consists of a thick pad of leather stuffed with grass, attached in front to a wooden arch. The loads are tied close together and laid on the pad so that the weight rests on either side of the animal's spine, the whole is secured in position by raw-hide thongs (*machanyas*) which pass under the animal's belly and are finally tightened by the united efforts of two men, feet against the loads, who haul with all their might. The arrangement of the thong is said to be similar to that of the "diamond hitch" used in some parts of the Americas. This method of loading has considerable advantages in Abyssinia. It places the loads high up and close together so that they pass easily through narrow defiles often met with on the roads and can cross fairly deep streams without risk of being wetted. It has however the very great disadvantage that the raw-hide thongs passing underneath the animal's belly rapidly produce deep sores and in the course of a long journey many animals may be incapacitated.

The ordinary Abyssinian mules are small animals and it was found that the Egyptian mule pack saddles were far too large for them. The Egyptian Army donkey pack saddles proved quite suitable as regards size and are probably kinder than the local pattern, but, as supplied, the loads hang out farther and lower, so that they are liable to get wet crossing streams and they are awkward or even impossible for traversing some of the narrow winding tracks that are common. The far overhanging loads either cannot get through or get badly knocked about in doing so. These saddles might be improved so that the loads should rest higher up. This might be done by placing a pair of T-like pins on the centres of the arches so that the loads on both sides would hitch on these " bollards " and would be in almost the same positions as those on a mule loaded Abyssinian-wise. It has been suggested that the existing hooks might be reversed, the loads being hooked on from opposite sides, but this is open to the objection that while one load might be easily hooked on, it would interfere with the hooking of the other, unless long loops were

made and this would defeat the object of the alteration. The saddle pads should be continuous under the arches so as to prevent any possibility of the wood coming down on to the animal's spine. These pack saddles are secured in position by girths, cruppers, and canvas webs passing round the breasts. On rough tracks the saddles may slip and then the cruppers are liable to chafe and make sores. It was found advisable, even with these saddles, to secure the loads by *machanyas* in Abyssinian fashion to prevent them from flapping against the animals' sides as they trotted and from being jogged off completely.

Two or three sheepskins are used to form a numnah beneath the Abyssinian pack saddles. Any party having to use animal transport should be well provided with numnahs. Old army blankets, which may sometimes be purchased cheaply, can be cut in halves, folded and sewn up to make thick pads which serve the purpose well. The use of such numnahs not only helps the animals but also tends to preserve the saddle pads, as these do not come in contact with sweaty skin.

There is clearly a great deal in favour of loading animals by methods that the people understand and the question arises as to whether short girths of wide canvas might not be adapted for use with the Abyssinian method of securing loads. About 2 feet long, they would pass beneath the animal's belly, and being provided with D-shaped metal eyes at the ends, the raw-hide thongs securing the load would be tied on to them and would not pass under the belly. Some such girths have been made but the results of trial are not yet known. In any case it can hardly be expected that such an innovation will be easily adopted by a conservative people. The matter is, however, important and deserves attention, for, apart from any consideration for the animals, if the Abyssinian method of securing loads can be modified so that animals are not quickly galled, it will lead to far greater efficiency. This may have a very direct bearing on the amount of mule transport available when large quantities of materials have to be transported, as, for instance, for the construction of regulating works at the outlet of the lake.

Abyssinians are in the habit of tethering mules by the hoof and it seems best for the ropes all to be secured to a length of stout rope tied between two stakes or trees. The objection to this method is that apart from deterioration during the rains, the mules destroy the ropes. Chains and headstalls may with advantage replace tethering ropes and failing headstalls, the chains might be used with short lengths of rope passing round the animal's legs. A *zeriba* or light stockade was tried for the purpose of securing mules during the night and it may be satisfactory on higher parts of the plateau where mosquitoes are absent. Near the lake, however, it seemed to harbour these insects, and it certainly screened them from the wind, so that they were free to worry the mules, and these, unable to rest, were liable to burst out. Tethering has the great advantage that the animals stand in the open and have the benefit of any breeze to keep mosquitoes away. Abyssinians hobble horses and mules with a leather thong fastened from the neck to a hind leg. It is hardly necessary to add that brushes and curry combs must be provided so that animals may be kept clean and the incidence of ticks reduced. There should be burnishers and supplies of saddle soap so that saddles and bits may be kept in good order. While on the march, grass should be cut for the mules to provide them with fodder during the night. Sickles must be provided for the purpose and are best imported from outside. Those made locally in Abyssinia are of poor quality and expensive, while quite satisfactory articles are manufactured by blacksmiths in Sudan markets.

Boats.

Barges will be required on the lake for the transport of materials when works at the outlet are being constructed. Meanwhile, the earliest opportunity should be taken of putting on a sailing boat large enough to be safely sailed about the lake and capable of taking about a ton of cargo. Craft of transportable steel sections are sold by English manufacturers and one about 25 feet long with safety air tanks would probably serve the purpose well. Such a boat would certainly faciliate communication across the lake, providing rapid means of carrying stores and mails from Delgi.

Rope.

The people around Lake Tana use very little rope and supplies of good quality are practically unobtainable. The place of rope is taken by *machanyas*, the raw-hide thongs which, besides being unsuitable for many purposes, are expensive and very liable to the attacks of insects and rats. For these reasons the traveller is recommended to have ample supplies of rope, not only for tying loads but also to meet the many needs of a camp, such as replacing tent rope, etc. Skins of slaughtered cattle should be either saved for making into *machanyas* or they may be readily sold for such a purpose.

Mule Loads.

The ideal load for animals seems to be formed by material such as grain or even sand, which can be carried in bags and, accommodating itself to the outlines of the back, exerts an even pressure over a relatively large area. There can be no question but that all materials such as flour, salt, granular sugar and cement, can be far more efficiently transported in bags than in boxes. Bags have the advantage of lightness but there are many purposes for which boxes must be used.

A mule will carry up to two hundred pounds if divided into two convenient loads. The size strongly recommended for a mule box is :—

Internal measurements ... ... $34\frac{1}{2} \times 34 \times 49$ centimetres.
Approximate external ... ... $38 \times 38 \times 53$ „

This will hold 18 No. 2 sized biscuit tins and is convenient for other stores and drinks in large bottles. The ordinary mule box, $26 \times 26 \times 67$ centimetres outside measurements is not such a useful shape and does not hold as much. A length of 80 centimetres was found to be too long, extending beyond the saddle pads and being liable to cause sores. The over-all length of loads should not exceeed 70 centimetres. In 1920 a number of iron boxes, size $25 \times 38 \times 60$ centimetres over-all, were filled to total weights of 50 lbs. On account of their lightness these were tied together in pairs so that a mule carried four and appeared fairly conveniently loaded. Such boxes filled to weights of 100 lbs. make good loads, while the over-all size of the pairs $38 \times 50 \times 60$ centimetres is perhaps rather too large. Some canvas-covered basket paniers, so-called mule paniers, were also tried but proved unsatisfactory for several reasons. They are too wide to form convenient loads, too deep for packing and their net weight of 26 lbs. is unnecessarily great. A size of $43 \times 53\frac{1}{2} \times 61$ centimetres outside measurements, has been officially recommended as convenient for a mule load. This is even larger than the pair of iron boxes referred to above, and is certainly too large if the contents are likely to be heavy. The actual size of load is a matter on which each

traveller is likely to have his own particular predilections and these may be modified according to those of the *negadis* who deal with his transport. On the whole the loads should be as compact as possible and not too long. The boxes should all have hinged lids made to fasten with padlocks. A very convenient form has about one-third of the top permanently fixed with the lid hinged on to it and covering the other two-thirds. The advantage is that the lid, when open, lies back on the fixed part of the top and forms a shelf where things may by put while unpacking. The hinges cannot be wrenched off by the weight of the lid when opened and they are less likely to be damaged by attempts to close the box when it is too full. They may have battens at the ends and on the lids but not at the sides, and for most purposes there is no need to make them with dovetailed angles. Air and watertight iron boxes of the kind often used by travellers in the tropics were not tried and it is doubted whether they would be worth the extra expense, considering the rough treatment by mule transport which would certainly result in their being soon dented and rendered no longer waterproof.

Donkeys were not used during the Tana Mission of 1920–1921. Some travellers speak highly of them as compared with mules, but they are certainly not good during the wet season. They carry a total of about 120 lbs. distributed in two loads of 60 lbs, each

Packing.

Mule transport over rough hill tracks in Abyssinia is most destructive. The continual jog of the mule's trot added to inevitable encounters with trees and rocks beside the track will wear any articles that are at all loosely packed. Tablets of toilet soap in any ordinary cardboard box may be worn half away and paper packets are almost certain to be holed. For these reasons paper bags should be avoided and all such things as rice, macaroni, Epsom salts, boric acid, etc., should be in calico bags and packed in the wooden or iron boxes. Goods transported in sacks require some protection against rain. Waterproof sacks may be used, but probably it would be more satisfactory to use ordinary sacks and have waterproof sheets that can be thrown over them in case of rain.

Padlocks.

Common padlocks, may be used for the store boxes and a great deal of trouble will be saved if it is recognized in buying quantities that though separate keys are supplied for each, there are unlikely to be more than six varieties of the same kind of lock and that a single key may be used to open all the padlocks of each one of these varieties. Several really good padlocks may be required for use on cash boxes.

Tents.

The ordinary 11 × 9 feet size double fly tent made of Willesden canvas proved quite suitable for the members of the Tana Mission, the senior members having one each and the junior staff one for every two. The Willesden canvas rots when exposed to weather and possibly untreated tenting lasts longer. That supplied by the Elgin Mills Co., of Cawnpore, is highly spoken of. Unless a stone or mud and stake built house can be provided, a tent should be maintained for use of the camp guard and where the money chest may be placed with relatively little risk of fire. For the same reason it may be advisable to keep all important

papers and documents in a tent. In the event of a fire, a grass hut is very inflammable and it is rare that any contents can be saved. A good sized tent is required for the office, while ordinary, military pattern, bell tents with single central poles may serve as guard and store tents. Several of the latter should be taken if it is proposed to make a permanent camp. For journeys in Abyssinia during the rains, tents must be provided for servants, escort and muleteers and the most convenient type for the purpose is the locally made Abyssinian tent. It is made of double thicknesses of unbleached calico supported on a ridge pole resting on two uprights all of bamboo, the sides come right to the ground and are provided with loops for pegging down. Forty-five yards of cloth are required for a tent for four muleteers while 60 yards or two bolts are enough for a larger tent suitable for an interpreter. It appears that almost all Abyssinians met with by the Tana Mission know how to make such tents and all that is required is to provide the men with the cloth, some needles and the cash to buy poles. The rain does not beat through but is apt to blow underneath. They are good shelters in the dry season.

Waterproof Sheets.

It is extremely important to have good supplies of these for several purposes. The 6×3 feet size should be supplied to servants and police taken from the Sudan and the 6×6 feet size proved extremely useful for protecting special loads from rain while on the march. It is a mistake to suppose that either paniers covered with waterproof canvas or iron boxes are really waterproof. They soon get holed and in any case a driving rain will find its way in. Besides, the muleteers are quite likely to stack the boxes upside down so that the lids catch any water running down the sides. For such reasons, there should be at least enough waterproof sheets, 12×9 feet size or larger to protect all baggage while camping. Waterproof sheets are useful in permanent camps where stores may be kept stacked under them or they may be used to make temporary shelters for men. Ground sheets must be provided for tents or for grass huts occupied by the staff but they must not be regarded as damp proof. Moisture passes through, condensing on anything resting on them, so that boxes should always be supported on pieces of wood or stone. There is no need for a ground sheet to pass under them and in fact if it does so it will merely perish where the stones or pieces of wood press it in close contact with the moist ground beneath. Moisture condensing on the bottoms of iron boxes may find its way through the seams, as these are not usually airtight, and continual vigilance must be exercised with regard to those that have to rest on the ground. This trouble is all avoided by using supports of wood or stone high enough to allow free circulation of air.

Camp Equipment.

Men's Requirements.

Every four men of the servants and muleteers during a journey in Abyssinia expect to be supplied with :—

1 cooking pot.
1 water bottle.
4 mugs.
1 circular iron pan or sheet for baking unleavened bread.

On forming a permanent camp, the men are likely to arrange with villagers for the supply of food and will no longer require these utensils, which should for the most part be collected and stored.

Water Tanks and Bags.

Water in the neighbourhood of Lake Tana is always found at points conveniently close and there are no long stretches of road over which travellers must carry supplies. Means of transporting water ,however, are required to enable water to be brought to camps which may not be situated in the immediate vicinity of the source of supply. The water has only to be carried short distances, consequently mules can take fairly heavy loads. The ordinary 10-gallon camel *fantass* or water tank is quite suitable and the canvas water bags used on donkeys in the Sudan and holding a similar quantity may prove even more serviceable, especially for a permanent camp. They can be laid directly on the animal's back without need of a saddle.

Sundry Equipment.

A few general notes may be useful but there is no need to detail ordinary requirements such as kitchen and table outfits.

Camp Fireplace. Ras Hailu presented the Mission with a little portable fireplace consisting of an iron tray about 40×60 centimetres with sides about 8 centimetres high and standing 20 centimetres above the ground on legs. Chain loops were attached on two opposite sides and enabled the fireplace to be carried about while the fire was burning. This contrivance proved very useful. A fire was made up on it and left outside until smoke ceased to be given off, then it was brought into the tent and proved most welcome on cold and frosty nights.

Umbrellas are likely to be useful during the rains for both staff and servants. They prevent the rain running down the neck without the need of a helmet, which becomes soaked, spoilt and takes a long time to dry. They give quite enough protection for a servant crossing from the kitchen at meals and they or southwesters might be useful too for men who have to stand out on watch.

Meat Safes can easily be made of muslin held in position with hoops of thick wire. The Abyssinian climate is cold and meat lasts well if flies can be kept off.

Liqueur Glasses. These are most useful for giving small drinks of brandy to Abyssinian visitors who have to be entertained.

Gramophone. One of these may be most useful in entertaining Abyssinian guests. They like violin and cello music, bells, and songs with laughter.

Kitchen Outfit. This should include a large kettle with a spout, for boiling water for filling drinking water bottles, baths and washing. Some iron bars or a grid may be very useful for making a camp fireplace. Some form of oven is required for baking bread.

While on a journey a hole in the ground covered with an iron sheet may be used as a temporary oven, but in a permanent camp something better is required.

Tools. The traveller's requirements as regards tools depend mainly on his object. Besides a small outfit of tools, he should be provided with saddler's awls and needles for repairs to saddlery and canvas articles. The very great use of billhooks for clearing bush may be emphasized, and while surveying at the outlet they proved to be far more useful than axes. Where there are quantities of thorny creepers, pruning scissors would certainly be handy. A small cross-cut saw proved serviceable both in cutting trees while clearing and in camp for cutting logs for firewood. A pick and hoe must be available for digging trenches around tents.

Traps. Small rats or large mice proved quite destructive and a supply of traps should not be forgotten.

Personal Outfit.

Waterproofs or Raincoats.

Waterproofs or raincoats are essential for senior staff during the rains. There is a good deal to be said in favour of a waterproof cape as against the coat, but this is largely a personal matter.

Gum Boots.

These are also essential for camping in Abyssinia during the rains, for without them the feet would very often not be dry. If the grass is not sodden with rain, it is wet with dew both in the evenings and early mornings. Knee gum boats are also some protection against mosquitoes, but thigh boots would be better.

The climate of the Abyssinian plateau may be really cold at certain seasons and the traveller should be well provided with warm clothing. The evenings, nights and mornings are cold, while the middles of the days may be quite warm (*see* Chap. III). It is convenient, therefore to have warm clothes that can be easily put on or taken off. An overcoat or a good tweed jacket served the purpose well, while a sweater may be very useful. The staff found jerseys very satisfactory.

Men's Outfit.

Servants, escort, etc., taken from the Sudan should each be supplied with two good blankets, an overcoat, a woollen jersey, khaki drill shirt and shorts, puttees and either boots or sandals as well as the 6×3 feet ground sheet already mentioned. The overcoats of ordinary army pattern were much esteemed, but in the rain they become sodden and take a long time to dry. On the whole they are probably the best thing of the kind to supply to men brought up from the Sudan, as they protect them from the cold, while the rain can often be avoided. The Abyssinian *burnus* deserves consideration too as a useful garment for men both as regards rain and cold. They cost about 8 dollars in Addis Abbaba and

are about double that in Gojam. They are very commonly used in Abyssinia and are peaked capes of heavy woollen material which when properly worn in rainy weather cover the head and shoulders, having a hole for the face and protecting the body from the rain. The Abyssinian escort and muleteers expect to be supplied with *burnuses* for journeys and it is useful to have a supply for special duties in permanent camps, the garment being passed from one man to the next.

Servants from the Sudan will certainly demand to be supplied with sandals or boots. Abyssinians always go barefoot and it was found that the men from the Sudan soon discarded their heavy foot gear, consequently it is probably better to offer them cash in lieu of sandals.

Seals.

Abyssinians do not understand the use of signatures, but every person of importance has his seal or stamp for the purpose. They are generally fairly large and the standing of the owner may be gauged from the size. That of a Ras is generally about two inches in diameter and those of his subordinates correspondingly smaller. It is recommended that any traveller making a long stay in Abysisnia should be provided with an Amharic seal making an impression about an inch square or a little larger. Failing a specially cut seal or one with Amharic characters, an ordinary office dating stamp or even a monogram such as those used for marking linen would probably serve. For official Missions the seal may be rather larger, perhaps $1 \times 1\frac{1}{2}$ inches, and inscribed with the name of the Mission in both Amharic and European characters. The ink impressions of such seals at the foot of letters serve to authenticate their origin, but in the case of Europeans they should always be accompanied by the ordinary signature. It should always be understood that the signatures are the valid marks of Europeans while the impression of the seal alone carries almost no weight.

A small seal for use with wax is often required when closing letters, parcels or mail bags.

Firearms.

The introduction of firearms into Abyssinia is regulated by international conventions and the intending traveller should take early steps to obtain special permission for the entry of the weapons for his own use. This should be done through his Consulate at Addis Abbaba or the Intelligence Department in Khartoum, according to the route to be adopted. In the course of the Tana Mission journeys during 1920 and 1921 little large game was seen and this is doubtless a consequence of the large number of local sportsmen who are armed with rifles. Birds were not numerous, but during the rains geese and duck are to be found on many marshy streams and in their season there are snipe and quail. A useful armoury might include a high velocity rifle of bore less than ·350, a ·220-bore rook rifle and perhaps also a shot gun. Rifles of good quality should be selected for the sake of appearance, as Abyssinians measure importance by the type of the traveller's personal weapons. If they are too striking trouble may arise from demands by covetous chiefs. Some of the best English makers' names are well known in Abyssinia.

Amharic Grammars and Dictionaries.

The series of books written by Mr. C. H. Armbruster is certainly the most authoritative. This includes an Amharic grammar, 1908, P.T. 60, and an English-Amharic vocabulary, 1910, P.T. 75, which are probably enough for most purposes of the ordinary traveller. One volume of the Amharic-English vocabulary has already appeared and like the others has been published by the Cambridge University Press and is obtainable in the Sudan from the Intelligence Department. The "Amharic Manual" by Major Alone, published by H.M. Stationery Office in London is a useful little book of a handy size for carrying in the pocket while on a journey.

Supplies.

FOOD AND DRINK.

The extent to which a traveller's needs may be met by the ordinary resources of the country may be gathered from Appendix I. Beef, mutton, chickens, butter, milk, eggs, potatoes, onions, coarse flour, trade salt, and coffee can almost always be obtained. Milk is abundant during the rainy season but the supply falls off as the dry season progresses and then tinned milk should be available. If the traveller is prepared to use local butter and suet for cooking purposes, tinned dripping is only required as a stand-by. He should however be well supplied with sugar, soap and tea and those are probably the most essential items. Dried fruits and vegetables such as apple rings, apricots, prunes, butter beans, peas and lentils are much lighter to carry than the tinned varieties, but supplies of both kinds should be taken. Flour, table and kitchen salt should also be provided, and for the rest, such as tinned meats, puddings, condiments, etc., the traveller must make his own choice.

Abyssinians make a light beer (*talla*) and also mead (*tej*) and both these, when nicely made, are quite palatable and may to a limited extent replace imported drink on the traveller's table. Apart from these, all beers, wines and spirits must be brought and in making the selection large bottles should be preferred to small ones, as when empty they may be bartered with the Abyssinians in exchange for fowls, etc., while small bottles have no value. Here again the selection must depend on individual taste but should include ample supplies of brandy for entertaining chiefs or other visitors invited into the tent. The traveller must drink with his guest and the brandy may be of any ordinary kind good enough for the purpose. Sweet champagne and liqueurs are much appreciated by important guests.

MEDICAL STORES.

It is difficult for a layman to advise on the selection of medical stores, but a doctor and preferably one who has sojourned in Abyssinia should be consulted. Any traveller must desire to help sick people who appeal to him and, as soon as it is known that medicines are being distributed, the number of applicants may become quite large. The ordinary traveller will probably not go farther than giving simple purges, quinine, bathing eyes and dressing wounds and sores, and ample supplies of materials should be available. Calomel ointment seemed very effective for many of the sores, while boric acid did not appear to be much help to the eyes, but possibly zinc sulphate would have been better. Supplies of small specimen tubes $2 \times \frac{1}{2}$ inches are useful for giving small quantities of ointments or

iodine, so that dressings may be replaced later. Safety pins, forceps and scissors for cutting bandages should not be forgotten.

Liberal supplies of insect powder should be available and it is preferably packed in tins so that its strength may be preserved. That packed in cardboard boxes is often found to have deteriorated.

Veterinary Stores.

The most necessary are washes, lotions or ointments for sores. Jeyes' fluid and iodoform are useful and there should be a good supply of cotton wool, but veterinary guidance should be obtained in making selections.

Garden Seeds.

Anyone camping near the same spot throughout the rainy season in Abyssinia should be supplied with seeds. With a view to adding variety to the table, the vegetables should include radishes, cabbage, lettuce, peas, beans, cucumbers, and marrows. In selecting these it is well to remember that potatoes, onions, peas, beans, cabbage and pumpkins are cultivated by the people. The potatoes are good but small, and there is no object in bringing others unless to introduce large kinds. The peas are small, and tough-skinned and European varieties of peas and beans are welcome. Apart from the benefits of having an additional supply of fresh vegetables, the people often come and ask for seeds and would certainly be glad to have them.

Some flowers may be of interest, and zinias, carnations, mignonette, poppies, etc., all thrive as long as the rains continue. Almost any kind of European flower seed will probably germinate and thrive.

Timber is a real want in the country and priests like to have tall trees around their churches. Addis Abbaba is smothered in Eucalyptus, which certainly gives shade and firewood, but the timber of that particular variety is of poor quality. Seeds of fast growing pine trees such as *P. canariensis* and *P. pinaster* might be worth trying and presents of the seed or seedlings would certainly be welcomed by priests.

Cloth.

A supply of unbleached calico (*abu gedid* or *melakan*) should be available. It is useful for tents and may be sold or issued to men for clothing. A dozen yards of muslin will also meet a number of requirements.

Sacks.

The Abyssinians make nice leather bags but sacks are continually in request for various purposes such as men's gear, forage, etc., and good supplies should be available.

Presents.

This is a most difficult matter on which to give advice, as novelty must generally be aimed at and requirements will change from time to time. The more important chiefs visit Addis Abbaba and are familiar with most things exported from Europe. These they see either in shops or in the houses of Europeans who entertain them. One important chief who was visited possessed an excellent rifle, wore a gold wrist watch and produced a very fine pair of binoculars, and it was clear that in presenting him with a gold watch, it was merely a case of adding another to an already large stock. For official Missions and duties that are likely to involve long stays in the country there can be no doubt that it is preferable to give presents at intervals to the important chiefs as well as to the minor local ones. More attention is likely to be gained by a succession of small presents than by a single more valuable one and there is much in favour of giving useful articles that wear out in due course or consumable stores such as groceries, wines and spirits. The following list may be of assistance to the traveller.

Firearms.—International agreements preclude the introduction of firearms into Abyssinia except under special permission for the traveller's personal use and any demands for either arms or ammunition must be rigidly discountenanced.

Watches of all varieties, preferably with hunter cases or well protected faces, and with chains are liked, but it is open to considerable doubt whether they are to be regarded as useful presents.

Swords.—These should have curved blades such as the Indian cavalry pattern made for Abyssinia by Messrs. H. Wilkinson, Pall Mall. Straight blades are not appreciated.

Pocket-Knives.—Rather good qualitites are demanded, preferably with a number of different kinds of blades and tools and with a loop for attaching to the belt. Nothing that costs under half a sovereign is likely to be appreciated by even small chiefs.

Razors.—These form useful small presents.

Shaving Mirrors should be of good quality.

Blankets, red or white in colour, are good presents.

Mechanical Electric Torches.—The ordinary torch with refill batteries rapidly becomes useless and should not be taken.

Church Bells.—The size is limited by the weight of a mule load, but bells approaching 100 lbs. in weight form good presents.

Crockery and Glass.—Sets of plates, coloured coffee cups and saucers, as well as tumblers and wine glasses are welcomed by small chiefs.

Tents, Tables, Chairs and Camp Beds.

Clothing.—Clothes of European style, with the exception of hats, are not used in Abyssinia. Hats are very popular if they have wide brims. Helmets too are welcomed. Capes of black or dark coloured silk, fastening with gilt buttons might be appreciated. Coloured silk scarves are in demand.

Umbrellas and Parasols.—Both these are appreciated. They should not be of red colour, as this is an Imperial prerogative, but parasols with good patterns are used by priests for processional purposes.

Soap.—Boxes of toilet soap.

Bibles, Psalms, Holy Pictures and Incense.—Bibles and psalms are printed in Amharic or Güze and issued by the Bible Society, but Amharic versions are discouraged by the priests. The holy pictures are coloured prints of religious subjects and are welcomed by priests and at churches. Incense is also appreciated at churches.

Books.—School books, printed in Amharic, including geography, history, etc., are obtainable in Addis Abbaba and would certainly be welcomed by priests and small chiefs.

Coloured Cloth or Chintz of bright colours is used for church vestments, curtains and drapings, and lengths of about two or three yards are much appreciated. A piece of coloured silk would be a very handsome present.

Toys.—Mouth-organs, dolls, tennis balls, tin whistles, toy watches, etc., may be acceptable, especially among children or to chiefs who have children. The production of a doll or a mouth-organ delights the crowd of retainers who accompany an important man, but this is merely due to novelty and would soon wear off.

Writing Materials.—Writing paper and envelopes form useful presents to chiefs who have a good deal of correspondence. Writing paper is often sought by priests and pupils and quite likely slates and slate pencils would prove useful at churches where schools are conducted.

Drinks.—The custom of offering Abyssinian guests a glass of brandy has already been referred to and there can be no question that bottles of brandy form much appreciated presents. For this purpose the traveller should be well supplied with any ordinary quality and it should be in full-sized bottles. Sweet liqueurs such as crème de menthe, peppermint, cherry brandy, and benedictine would certainly be liked, as was found to be the case with champagne. Sweet brands of the latter are preferred and some of the sparkling Italian wines might suit well. A case or two of champagne would certainly be welcomed as a present by the most important chiefs.

Groceries.—Tinned vegetables, fruits and jams occasionally appear among the dishes served to entertain strangers and there can be no doubt that cases of well selected groceries are useful to important chiefs. Tinned meats, however, should be rigidly excluded. The selection, besides the items mentioned, may include sardines and other tinned fish, sweet biscuits and sweets of various kinds. In making such presents tin openers and cork-screws should be included.

Breeding Animals.—Good stallion horses or donkeys form valuable presents to really important chiefs and such gifts have the advantage that the quality of Abyssinian animals may be improved. Trade will benefit in its turn when there are better animals for export. Quite probably it may be some time before Abyssinians become sufficiently interested in breeding to take full advantage of good stud animals. However, this can be remedied by experience and gifts of good breeding animals will enable the results to be appreciated. Similarly good cattle and sheep might be introduced, but such animals should only be given to important chiefs who have the welfare of their people at heart and who may be expected to attempt to breed from the imported animals and not merely keep them as curiosities.

Articles for Barter.

The absence of small change in Abyssinia makes it desirable to have supplies of articles that can be exchanged. The value of the exchange no doubt depends to some extent on the man who does the bartering and on the local demand for the particular commodities available. About an ounce of cloves or a tiny bottle of scent may buy either four fowls or twenty eggs. Among the things that appear to be most in demand the following may be mentioned :—

Scents.—These may be bought in bulk in Omdurman and are sold under the following names: *serrutia, beidah, magmuh,* and also *fleur d'amour.* The scent should be bartered in quantities of about a dram and little flask-shaped bottles proved very satisfactory. Possibly $2 \times \frac{1}{2}$ inch specimen tubes might suit well for the purpose, while $2 \times \frac{5}{8}$ inch would serve as a larger size for the cheaper scents.

Spices.—Those known in Sudan markets as *grunful* (cloves) and *mahlab* are useful.

Soap.—Quite small tablets about $2\frac{1}{8} \times 1\frac{1}{2} \times \frac{3}{4}$ inches, coloured and scented, are much in request. Ordinary washing soap is also requested in outlying places, but it is traded at some of the more important markets.

Needles.—Ordinary sized sewing needles.

Razors.

Looking Glasses, round ones about 3 inches in diameter with covers, or square ones, such as are met with in the markets of the Sudan, serve well.

Silk.—Black silk in the form of string or cord for making *matabs.* Coloured silks in skeins, red, blue, green and yellow are liked for embroidery. Saleh Abdel Hadi, a Cairo merchant, is said to be famous for silks. His trade mark is two pyramids with a gazelle above, and his dark blue, almost black, silk is most esteemed for *matabs.* Black silk cloth is in demand among important chiefs for the purpose of making presentation robes.

Muslin.—The variety known as *shash* in Sudan markets can be traded in small pieces. It is used for head-dresses by women.

Bottles.—An empty large bottle may be exchanged for a number of eggs or several fowls, but the half-bottle, pint size, is worthless and almost nothing can be obtained in exchange for it. Even squat shaped whisky bottles are looked on askance with the remark that they are small. Lime-juice bottles are accepted at lower values than ordinary bottles. There can be no question of bringing empty bottles for the purpose of trading, but any bottled stores or drinks should be brought in large bottles. Bottled fruits may be preferable to tinned for this reason. Jam jars are popular as drinking cups.

APPENDIX V.—WATER SUPPLY OF ADDIS ABBABA.

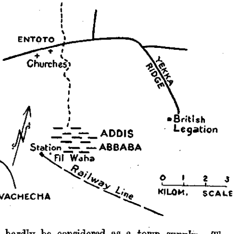
These explorations of the water supplies were undertaken at the request of H.H. Ras Taffari, who provided a guide to take me to the various springs.

Springs North of the Town.

To the south of Entoto there is a valley with a corrie-like head containing important springs; one of these yields about 180,000 litres a day while smaller springs on the eastern side of a small ridge yield about 30,000 litres a day. There was a small farmstead near the springs. The water from the springs unites in a stream, passes over a waterfall with a drop of about 20 metres, and lower down it is collected in a small aqueduct, which runs along the west slopes and is said to carry the water to St. George's Church in the city. The springs at the head of this valley could easily be led into pipes and, in view of the leaks and seepage along the aqueduct, St. George's might be supplied with as much as it receives at present and there would be a big margin for other consumers.

These slopes are formed of a light coloured tuff and several small springs of little importance occur along them to the west. Farther on, at a point two kilometres north of Rufail Church, a good spring was met with at the head of a narrow valley, where it issues from below a compact, trachytic looking rock, resting on a compact banded tuff. The spring yields about the same quantity of water as the main springs at Entoto, and it could easily be led into pipes.

About 600 metres south-east of Entoto Church and about 300 metres west of the Salali road, several springs are collected into masonry heads from which pipes carry the supply to the Empress's Gibbi. The water from an upper head is piped on to the lower at an altitude of about 2,780 metres and into which several springs are also collected. Most of the springs occur on a level of about 20 metres above the lower head. Some of the water is led in by open channels with the result that turbid surface water is admitted, and the source is open to any pollution that may be washed in. In the vicinity there are inhabited huts, which should be removed if the supply is to be protected from pollution. There was no means of measuring the flow, but the volume appears to be slightly less than that of the springs to the south of Entoto. A collecting pit was being made to catch the water from a spring in a valley a little way towards the east. If all the springs around here were collected, a supply of about 180,000 litres a day might be available. This is an important amount, but it is already in use for the Imperial Palace, and consequently can hardly be considered as a town supply. These



springs are on the slopes of the Entoto ridge and are associated with a grey compact tuff.

At the pass, 3,410 metres above sea level, where the Salali road crosses the top of the ridge, there is basalt. The ridge rises to 3,490 metres, and from here it was followed round to the east. The arrangement of the branches is shown in the sketch. There is a branch running northwards, and east of this, at the north end of the Yekka ridge, there are good views of the east side of the range and of the country towards Ankober. Several small springs were met with along the ridge, but none that were seen were as important as the Entoto springs. There may, however, be others lower down in the valleys. On the surface of the ground there are many basalt boulders, but the prevalent rock exposed in the valleys is a light coloured grey tuff. The basalt boulders may be derived from intrusions through the tuff.

The Yekka ridge runs south-east to near the British Legation, and on its southern and eastern slopes there are several small springs, which feed streams that flow away southwards. These springs are too small and scattered for it to be practicable to collect them. On the south-west, the ridge is bounded for some distance by the ravine which passes the French Legation, but this appears to be too small and narrow to afford any large supplies of water.

The British Legation is situated against the south-west slopes at the southern end of the Yekka ridge, and an abundant supply of water for domestic purposes and for the stables is derived from a spring above the stables. On the south-east of the Legation and close to the house, there are other springs which yield water for the flower and kitchen gardens. It is extremely likely that the yield might be increased by opening up the spring with a channel dug into the ground just south-east of the house. The Italian Legation is situated against the Yekka ridge some distance to the north-west of the British Legation, and derives its water supply from springs in a similar way.

Springs in the Town.

There are good views over Addis Abbaba from the top of the Yekka ridge. Lij Yassu's *Gibbi* (Palace), which is situated on the same plateau and just to the north of the Imperial Club with its polo field, is seen to stand on ground that is surrounded by shallow ravines, so that the well water supplies are to be regarded as quite local and it would be impossible to increase their yields materially. Better well sites might be found on the lower ground farther south.

The Fil Waha, or hot spring, is situated on the floor of the valley between the railway station at Addis Abbaba and the Empress's *Gibbi*, at a level of about 2,360 metres. The water all issues at one spot, where it rises in two masonry tanks, each about 3 metres square, built over the source, and it was standing at about 2 metres above the level of the ground The floors of the tanks seem to be at ground level. The temperature of the water at the source was found to be 72° C, and the little ebullition which occurs is due to the rise of bubbles of gas. The water has a distinct sulphurous smell, but produced no discoloration on a silver coin which was submitted to it for several minutes. The actual content of sulphuretted hydrogen is therefore probably quite small. From the tanks the water is distributed to the bathing houses, and also to troughs where clothes are washed. There are two bath houses, one cheap and the other for the wealthy, each with large shallow baths fed from the hot spring, and where the bathers all congregate in the hopes of curing their various ailments. The flow through these baths is regulated so that the temperature is almost as hot as a man can bear, and when the custodian began to demonstrate by opening the tap wider, there was a hurried exodus from the water. It seems to be fairly soft, as it

makes very little curd with soap, and is much sought for laundry work. The water passes out of the enclosure, and outside, where it is cool, the cattle drink it. There is a dark scum associated with the water outside. The hot spring discharges about 160 litres a minute, and is to be regarded as an important source of water, the bulk of which is at present being wasted. It might be possible to increase the supply by boring on the spring but this would be quite problematic, as the fissures through which it rises may not be vertical. The existence of the hot spring in this position is of interest. It certainly occurs in a valley, but if the rocks below were not rather impermeable, the water would have been dissipated before reaching the surface. This does not bode well for obtaining large supplies from deep borings on the plains just below the city of Addis Abbaba.

In the town of Addis Abbaba there are several springs, and the most important is Ras Makonnen's, which is situated on the east side of the valley just above the bridge of that name. It has been provided with a masonry head with fountains, where people can go and draw water, but the supply was only about 2 litres a minute. It appears to have been much more important formerly, but either the channels have become choked and the water escapes in other directions, or more probably the supply has been impoverished by the eucalyptus trees.

Springs West of the Town.

On the west of Addis Abbaba, Fitaurari Hapta Giorgis has a supply, which is piped in from a shallow well in a field, where the spring is associated with a grey jointed tuff. The main supply, however, is probably derived from surface flow, and consequently is unsatisfactory. Near the spring is an aqueduct from the ravine at Rufail which is directly to the north. Close to the spring is a ravine, and the presence of this shows that only a small quantity of water can naturally be available at the spring, which is much higher than the stream bed. Moreover, gullies on the north-west side of the ravine expose a considerable depth of red clayey soil, which is certainly not favourable for water supplies.

Farther west, perhaps 7 kilometres distant from the town on the north Guleli road, there is a water mill at 2,580 metres altitude and close by is a fair spring quite well opened up, with a masonry head, and yielding about 60 litres a minute. The spring is situated near a rather deep valley, and alongside the mouths of some smaller tributaries. Its existence is difficult to explain, unless it is associated with a fissure, and its presence is therefore fortuitous. The spring belongs to Fitaurari Hapta Giorgis, who had the head works made and a pipe line laid towards the town, but it is said that the levels were wrong, and the pipe proved useless. The altitude, however, is certainly well above that of the town, but proper engineering is required.

The main stream in the valley carried about 180 litres a minute, and has been diverted for the mill. If this water were required for the town, it would have to be collected higher up the valley, and led round the hill towards Rufail. The country around Fit. Hapta Giorgis's spring is cut up by deep valleys, consequently the run-off is probably considerable, and it would be difficult to collect permanent supplies, if these exist farther away on the northern slopes of Managasha Mountain.

The valleys in this neighbourhood were further examined. That on which the mill is situated runs down to form the eastern branch of the western Akaki. At the junction the volume of water was about half that of the western branch. At a mill channel carrying

practically the whole discharge of the united stream it was estimated at about 60 litres a second. At this point the valley bed is at 2,420 metres or approximately the same level as the town of Addis Abbaba. The western branch of the Akaki is fed by a number of small valleys, each contributing small quantities of water and draining a plateau, the surface of which stands 2,560 metres above sea level. The stream beds are about 70 metres below the surface of the plateau. One branch crosses the Guleli road about 3 kilometres west of the Giorgis mill. Some of the water comes from springs in the western part of the Entoto range on the north, but a large part is derived from the lower plateau. The main stream, when it was measured, was probably swollen, so that the normal flow may be about three million litres a day. Even at this figure, it was the largest supply seen near Addis Abbaba, and the existence of a number of water mills suggests that a perennial flow can be relied on. Its level is low, and the water could only be led into the lower part of the town and filtration would be required if the water were taken from the stream, while collection from the various springs would be costly.

Springs East of the Town.

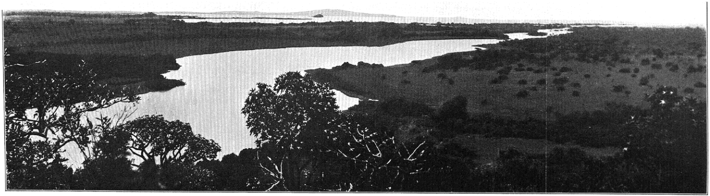
The country to the east of the Yekka ridge is traversed by a road which was followed to where it crosses the Akaki East at a distance of about 20 kilometres from the British Legation or about 25 kilometres from Addis Abbaba. At the stream the road divides, and the Wallo and Tigre branch goes in a north-east direction, while that to Ankober and Menz goes eastwards. The stream was carrying about 12 litres a second and contained small fish. The water rises towards the north-west and the principal springs are on a slope facing south. All the tributaries are small, and collection would be costly, but perhaps a head of about 60 metres above the level of the stream at the road crossing might be obtained. Aneroid observation at the road crossing shows that this is at about 2,570 metres and possibly water from here might be made to run to the lower part of the city.

General Conclusions.

The provision of a really adequate supply for the city of Addis Abbaba appears a very difficult problem, as the city is built on the slopes at a considerable altitude, and the springs above it are only enough to supply the needs of a few of the better class inhabitants. A supply of 200,000 litres a day in Europe would only suffice for the needs of one or two thousand people. In Addis Abbaba, if proper rights were granted, it would probably pay commercially to pipe such a supply into the town and to arrange for its distribution and sale, since a very considerable price, probably a dollar for 500 litres, could be demanded and would be paid in order to obtain safe water for domestic purposes and for drinking. Such measures are very remote from providing a really adequate supply for all the needs of the city. The town is situated on the southern slopes of the Entoto range, and there remain the northern slopes, which were not explored but which probably only contain small supplies of water comparable with those met with on the southern side. Failing a good gravity supply from such sources, which might be carried round in pipes, it is difficult to see how Addis Abbaba is ever to obtain the quantity of water that would be considered adequate

in an advanced city with the same number of inhabitants. The larger supplies of water are situated at low levels, and it is unlikely to be practicable to pump the water to heights of more than a hundred metres up the slopes to the town.

Addis Abbaba has been planted with eucalyptus trees, which thrive, give shade, and improve the aspect of the city. There have, however, been ideas that these trees dry up the ground, lessening the yields of springs, or have even deprived them of their supplies completely. In our opinion there can be little doubt that the eucalyptus trees must have an effect of this kind, and the present small yield of Ras Makonnen's spring is one of the results. If such an opinion comes to be held by the Abyssinian authorities, it is likely that much of the wood would soon be cut, and though the yields of a few springs might be improved, this would hardly compensate for the detriment to the amenities which the growth of trees provides for the town.



No. 35.—Northwards from a Point West of Photograph 14, showing the Irregularities of the First Reach of the Blue Nile.

APPENDIX VI.—NOTE ON THE FINAL RESULTS OF THE TANA MISSION.

Delay in the preparation of this report has rendered it possible to include notes of the work achieved until May 7, 1924, when the Tana Mission withdrew from Bahrdar Giorgis.

Surveys.

The outlet and the neighbourhood of the line of the proposed channel, right down to Arafami falls, has been completely sounded and mapped on the 1 : 1,000 scale. The surveys are complete, except for the mapping of the loop of the river around the Egirrbar Hills from the entrance of the proposed tunnel to its outlet and also the branch channel from Burifasas to Egirrbar. Time did not permit these to be done. The lake has been sounded for six kilometres outwards from the outlets where the floor of the lake was followed down to R.L. 70·00.

Meteorology.

Mr. Bambridge succeeded in carrying up a mercurial barometer, which was observed regularly from March 3, 1923, to January 16, 1924. By comparison with simultaneous readings of the mercurial barometer at Gallabat the lake has been found to be at 1,800 metres above sea level.

Pilot balloon observations of the upper atmosphere were also made and the fluctuations of the lake level followed during many seiches. All this material is available at the Physical Department.

A summary of the meteorological results is given herewith.

Evaporation.—Unfortunately the tank experiments of the subsequent Missions were carried out by junior staff and proved unsatisfactory, so that the readings have been rejected as unreliable. The meteorological screen built in March 1921 continued in use until March 1923, when it was found to be in very bad repair and was rebuilt to the same design. The same two Piche tubes were used continuously from June 1921 to April 1924 and were calibrated on return to Cairo. The observations have been compared with the actual lake losses during the period January to April in each year and a mean reduction factor of 0·41 has been found for the period June 1921 to March 1923, and of 0·64 for the subsequent period. A reference to p. 24 shows that this latter factor is the same as previously adopted for the 1920–21 observations. Using these factors in the corresponding periods the Piche readings have been reduced to lake evaporation (*see* Chap. III) with the following mean results :—

MILLIMETRES A DAY.

Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
3·9	4·8	5·1	5·7	4·1	2·4	1·1	1·1	1·4	2·2	2·4	3·2	1920–24
4·0	5·0	5·5	6·0	5·5	2·5	1·5	1·5	2·0	2·5	3·0	4·0	1920–21.

TABLE A.—METEOROLOGICAL OBSERVATIONS AT BAHRDAR GIORGIS 1921–1924.

MONTH.	1921.				1922.				1923.				1924.			
	Mean Temperature. °C	Mean Relative Humidity. %	Rainfall mm.	Prevailing Wind.	Mean Temperature. °C	Mean Relative Humidity. %	Rainfall mm.	Prevailing Wind.	Mean Temperature. °C	Mean Relative Humidity. %	Rainfall mm.	Prevailing Wind.	Mean Temperature. °C	Mean Relative Humidity. %	Rainfall mm.	Prevailing Wind.
January	—	—	3	—	15·4	48	0	S. 1·8	14·1	50	0	S 1·8	17·0 *(30·2)* *(3·9)*	64	1	S. 1·4
February	—	—	4	—	17·2	44	0	V. 1·8	16·4	46	0	NNW. 2·0	17·4 *(32·3)* *(2·9)*	47	0	S. 1·5
March	—	—	4	—	19·4	35	0	S 2·3	20·6	49	14	S 2·1	20·4 *(31·5)* *(7·7)*	58	21	S. 2·0
April	—	—	1	—	22·6	36	11	SSW. 2·5	19·0 *(30·9)* * *(5·4)*	45	33	N. 1·5	20·8 *(31·6)* *(10·2)*	52	61	S. 1·9
May	—	—	60	—	19·8	66	59	V. 2·1	19·4 *(29·4)* *(11·9)*	74	113	SSW. 1·5	—	—	—	—
June	18·0	73	135	S 1·3	18·6	70	123	V. 1·6	18·8 *(27·5)* *(11·1)*	78	88	SSW. 1·4	—	—	—	—
July	16·5	86	475	WNW. 1·0	16·6	86	415	WNW. 1·5	17·0 *(24·8)* *(12·3)*	87	377	WNW. 1·2	—	—	—	—
August	16·6	88	198	WNW. 0·9	16·6	88	401	V. 1·7	17·0 *(25·2)* *(11·5)*	89	310	SSW. 1·3	—	—	—	—
September	16·7	86	181	SSW. 1·3	16·8	86	194	S. 1·8	17·2 *(26·4)* *(10·5)*	86	334	V. 1·2	—	—	—	—
October	17·0	76	130	V. 1·3	16·6	77	114	S. 1·7	17·6 *(27·4)* *(7·5)*	78	50	S. 1·1	—	—	—	—
November	16·0	69	3	SSE. 1·3	15·6	70	16	V. 1·6	17·4 *(27·0)* *(8·0)*	78	41	S. 1·3	—	—	—	—
December	14·6	58	0	SSE. 1·7	14·2	65	0	S. 1·9	15·6 *(27·6)* *(4·4)*	68	1	S. 1·4	—	—	—	—
		TOTAL ...	1,194			TOTAL ...	1,333			TOTAL ...	1,361					

NOTES :— (1) Figures in brackets denote absolute maxima and minima. (2) "V" denotes that the wind direction is variable. * Doubtful.

Comparison of these figures with those adopted for 1920–1921 shows that our estimates for June and July were clearly too high and that 2·5 and 1·5 millimetres a day respectively would have been better. Our other figures are rather higher but otherwise compare well with the means just given, and this is what might be expected, since the total discharge of the lake in 1920–1921 was rather below the average of the four years. In view of all the circumstances, we prefer to adhere to the figures given in Chap. III save for the modifications indicated in June and July as set out in the second line above.

Hydrology.

The water levels of the lake and river continued to be observed regularly until the Mission was withdrawn. Discharge measurements were made daily during the flood and at longer intervals during the low stage season. A gauge-discharge curve for the lake, made from all the observations available, is given herewith. It does not differ from the 1920–1921 curve over the common part (*see* note on the permanence of the gauge-discharge relation, Chap. V, p. 64) and it is satisfactory to record that the figures given in Table IX (Chap. V, p. 72) for the discharge of the lake in a high year are confirmed. A short summary of the results is given below :—

TABLE B.—DISCHARGES AND LEVELS OF THE LAKE (1921–1924).

MONTH.	1921–1922.			1922–1923.			1923–1924.		
	Mean Lake Level.	Mean Discharge. m^3. p. s.	Total Discharge Millions.	Mean Lake Level.	Mean Discharge. m^3. p. s.	Total Discharge Millions.	Mean Lake Level.	Mean Discharge. m^3. p. s.	Total Discharge. Millions.
July	79·59	14	38	79·74	27	71	79·84	37	100
August	80·35	136	365	80·54	183	490	80·66	221	593
September ...	·87	298	774	81·10	419	1,086	81·14	444	1,150
October	·89	299	800	·02	368	987	·01	365	979
November ...	·63	193	500	80·73	232	600	80·71	233	604
December ...	·39	123	330	·46	140	374	·51	155	415
January	·19	77	206	·25	90	240	·29	98	262
February... ...	·02	50	122	·07	58	140	·11	64	160
March	79·83	28	75	79·90	36	97	79·92	38	102
April	·64	13	35	·73	20	51	·81	26	67
May...	·52	8	22	·63	13	34	·65*	13*	35*
June	·42	5	13	·64	13	33	·57*	10*	26*
TOTAL ...			3,280			4,203			4,493

*Estimated.

NOTE :—

	Maximum Discharge.	Lake Level.	Date.
1921	356 m^3. p. s.	80·95 metres.	September 26.
1922	459 ,,	81·14 ,,	,, 28.
1923	525 ,,	81·19 ,,	,, 22.

The Discharge of the Lake in an Average Year.

In Chapter V we came to the conclusion that 3,500 millions of cubic metres might be regarded as the average annual discharge of the lake. It is of interest to re-examine this question in the light of subsequent information. For comparison, the following table shows the annual discharges of Lake Tana, the Blue Nile and the Atbara during the years for which we have observations of the lake.

TABLE C.—ANNUAL DISCHARGES.

(Millions of Cubic Metres.)

YEAR.	LAKE TANA.	BLUE NILE.	ATBARA.
1915–1916*	3,600	40,100	7,800
1920–1921	3,500	47,300	11,100
1921–1922	3,300	45,900	10,400
1922–1923	4,200	54,300	15,000
1923–1924	4,500	51,900	12,000
MEAN	3,800	47,900	11,300

The Blue Nile, in the above table, is on the average about 9 per cent below the normal (1912–1924), but as the total Blue Nile discharge depends almost entirely on flood discharges, this difference from normal is of the order of accuracy of the figures involved. The Atbara is about 5 per cent below normal, but as all the figures previous to 1920 except 1913 depend on a gauge-discharge curve no great reliance can be placed on the normal.

An examination of the figures in Table C seems to throw considerable doubt on the existence of a strong correlation between the discharge of the lake and that of either the Blue Nile or the Atbara, but the number of observations is too small to enable us to say anything definite on this point.

If we take the mean of all the years for which we have observations the average annual discharge of the lake is 3,800 millions of cubic metres.

This is about 9 per cent higher than our previous estimate of 3,500 millions based on our own observations in 1920 and 1921. As the transmission loss between the lake and Roseires is and must remain very uncertain until the lake is actually functioning as a reservoir we prefer to regard the extra 300 millions as a factor of safety on our estimate of this loss (Chap. VII, p. 96) and to continue to adopt 3,500 millions of cubic metres as the discharge of the lake in an average year with the confidence that this figure preserves an adequate margin of safety.

Lake Tana as a Reservoir.

Mr. Bambridge was conversant with the outlines of the suggestions discussed in Chapter VII and it is of interest to find that after mature consideration of them on the spot, he is in almost complete agreement about them. He suggests that it might be better to close the northern outlet by a *sadd* running eastwards from near the north end of Debra

* The discharge of the lake in 1915-1916 is estimated from Mr. A. B. Buckley's observations, which show that the flood level in that year was about 3 centimetres higher than in 1920 and the levels from January to April very similar to those in 1921. Since half the total annual discharge of the lake takes place during the months of September and October, when the lake is near its highest level, and one-seventh of the total discharge takes place during the months January to April, the above estimate of 3,600 millions for the total discharge in 1915–1916 is almost certainly accurate to within much less than 10 per cent.

Mariam Island across to the slopes of the mainland. This line would be shorter than that following the row of islands across the actual outlet and the suggestion must certainly be considered when the works are designed. The line along the islands has, however, the merit of cutting off a considerable area of mosquito-breeding marsh, and though the bank would be considerably longer, a great part of it would not be more than about a metre in height.

The results of Mr. Bambridge's surveys of the lines originally proposed for the *sadds* are shown in Sections V and Y in the accompanying diagram, and these with W may be regarded as filling the gaps in Section 1. Section X is across the South Debra Mariam channel at Kilo 0·0, Maps III and IV, where it is suggested that the regulator might be built. Section Z is along the line of the proposed channel and tunnel, following approximately the line laid down on Map III. The biggest divergence is from Burifasas southwards, a more favourable line appearing to be about 150 metres east of that on the map. A revised estimate of the amount of excavation required, based on the new section, yields the following figures :—

	Cubic Metres.
Channel between regulator and tunnel	845,580
Tunnel ... ... } Channel at outlet of tunnel ... ... }	73,030
Drain to Arafami	9,730

The bed of the river proves to be rather higher upstream of Burifasas than was assumed as the basis of the estimates given in Chapter VII. The amount that would have to be excavated is therefore greater than our estimates. Soundings have shown that the bed of the river on the eastern side of the bend downstream of Burifasas is formed of mud. It is impossible to say what the depth of the soft material is, but the information tends to bear out the suggestion that excavation along this part of the line may be relatively easy as opposed to the hard basalt which would have to be dealt with in a channel around the Egirrbar bend, if this is adopted in preference to the tunnel scheme. The later surveys confirm the length of the tunnel as being 550 metres.

The levels at the outlet of the proposed tunnel and downstream of it to the Arafami falls all prove to be decidedly lower than those assumed as bases for our estimates. The amount of excavation that would be required for the drain is therefore correspondingly smaller. Possibly advantage might be taken of these lower levels by increasing the slope of the tunnel and making it correspondingly smaller. The flood level at the outlet of the tunnel is 65·00 and the level of the crest of the Arafami falls is 60·88 metres. Water level at low stage downstream of Arafami falls is 54·69.

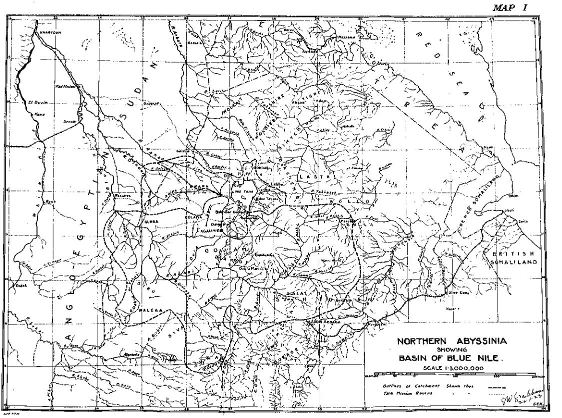
Health.

Dr. J. P. Mitchell and subsequently Major R. B. Black, D.S.O., R.A.M.C., have been present during the later stages of the Tana Mission. There appears to have been much less malaria than was experienced during and after the rainy season of 1920, but the later parties have travelled and reached Bahrdar Giorgis in comfort during the dry season and doubtless each has profited from the experience of the predecessors.

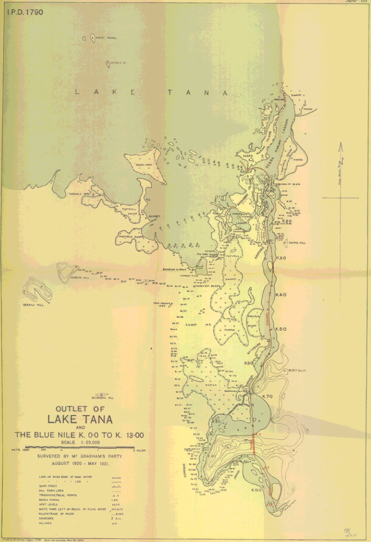
Mr. Bambridge relates that the " jigger " or sand flea has reached and become prevalent in the neighbourhood of the outlet. It appears to have been brought by men accompanying a chief who came and stayed at Zegi, and from there it has spread to the neighbouring districts. The people were quite unaccustomed to deal with the complaint and suffered severely. Possibly the spread of this parasite will modify what has been an almost universal habit on the plateau and many of the people will adopt some form of boot or shoe.

Government Press
10172-1923-1,100 ex.

MAP I


NORTHERN ABYSSINIA
SHOWING
BASIN OF BLUE NILE.
SCALE 1:3,000,000
Outlines of Catchment Shown thus
Tana Mission Routes
KHARTOUM
Wad Medani
El Dueim
Kawa
Sennar
Kassala
Keren
Massawa
ASMARA
RED SEA
ANGLO-EGYPTIAN SUDAN
ERITREA
GONDAR
LAKE TANA
LASTA
WOLLO
GUBBA
BELAIYA
AGAUMIDIR
GOJJAM
Debra Markos
WALEGA
ADDIS ABABA
SHOA
Dire Dawa
Harar
Jibuti
Zeila
FRENCH SOMALILAND
BRITISH SOMALILAND
Roseires
Kurmuk
Gallabat
Bahr dar Giorgis
Dangila
Lake Tana
Debra Tabor
WOLKAIT
TIGRE
Adua
Aksum
Makalle

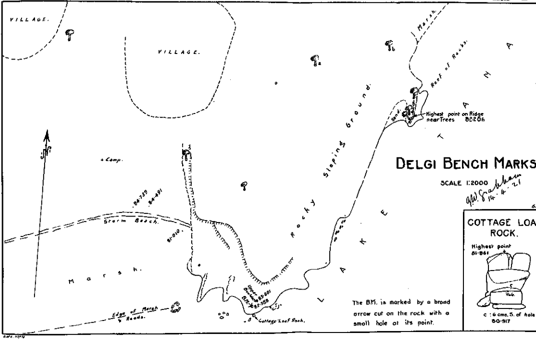

MAP II
THE COUNTRY AROUND
LAKE TANA
SCALE 1:500,000
THE MAP IS BASED ON THE LATEST COMPILATION OF THE SUDAN SURVEY OFFICE
WITH ADDITIONS BY THE TANA MISSION
1920-21
LAKE TANA
GORGORA
DEMBIA
KWARA
RAJGI
ACHAFAR
DURBETE
MEISHA
AGAUMIDIR
FAZOGLI
GUBBA
BELAYA
ZAKKA
SARAKWA



I.P.D. 1790
LAKE TANA
DEBRA MARIAM ISLAND
DEBRA MARIAM LAGOON
SWAMP
MARSH
PAPYRUS SWAMP
SHIMBET
SASSALA ABB.
AGUNA HARA
KOBIITA HILL
DEBANJI HILL
BAHRDAR GIORGIS
MARKET PLACE
FIG TREE GAUGE
TANA MISSION 1920
TAYIMA HILL
KAMFORO
ANTOBARR
BEZEIT ALLEN
KUTATINNA HILL
CHANNEL
K.2·0
K.3·0
K.4·0
K.5·0
K.6·0
K.7·0
K.8·0
K.11·0
K.12·0
OUTLET OF
LAKE TANA
AND
THE BLUE NILE K. 0·0 TO K. 13·00
SCALE 1:25,000
METS. 1000 0 1 2 KILOM.
SURVEYED BY Mr GRABHAM'S PARTY
AUGUST 1920 - MAY 1921.
LAKE OR RIVER BANK AT HIGH WATER
LOW
SWAMP EDGES
HILL FORM LINES
TRIGONOMETRICAL POINTS
BENCH MARKS
SPOT LEVELS
WHITE MARK LEFT ON ROCKS BY FLOOD WATER
KILOMETRAGE OF RIVER
CHURCHES
VILLAGES



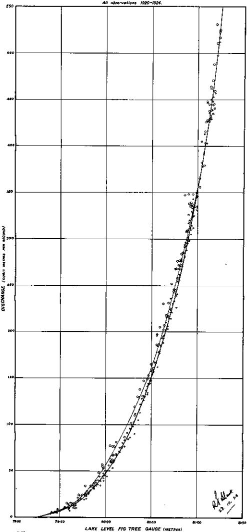
I.P.D. 3428
MAP IV
SECTION ACROSS THE OUTLETS OF LAKE TANA
ABBAI RAS
PAPYRUS SWAMP
MARSH (Dry in Summer)
LAKE TANA
DEBRA MARIAM ISLAND
DEBRA MARIAM LAGOON
DEBRA MARIAM CHURCH
SECTION ALONG ABBAI
CENTRE LINE OF CHANNEL
SECTION ALONG UPPER REEF AND ACROSS CATARACTS
SHIMABBO ISLAND
GRAETAAL ISLAND
IFWADDA ISLAND
IFWADDA LAGOON
MARSH
BLUE NILE
OUTLET OF
LAKE TANA
SCALE = 1: 5,000
SURVEYED BY Mr GRABHAM'S PARTY
AUGUST 1920—MAY 1921
LAKE OR RIVER BANK – ROCK – AT HIGH WATER
LOW
MUD OR EARTH
SWAMPY OR GRASS
FORM LINES
CONTOUR LINES
SECTION
Mr BLACK'S TRIG. POINTS
Mr GRABHAM'S
PLANE TABLE POINTS
BENCH MARKS
SPOT LEVELS


VILLAGE.
VILLAGE.
+ Camp.
84·739
84·491
Storm Beach.
81·010
Marsh.
Edge of Marsh & Reeds.
Rocky Sloping Ground.
Marsh.
Reef of Rocks.
Sand
Highest point on Ridge
near Trees 82·206
LAKE TANA
Upper Boulder 83·801
B.M. 82·558
Cottage Loaf Rock.
DELGI BENCH MARKS.
SCALE 1:2000
G.Y.K.
The B.M. is marked by a broad arrow cut on the rock with a small hole at its point.
COTTAGE LOAF ROCK.
Highest point
81·861
Hole.
c : 6 cms. S. of hole.
80·917

LAKE TANA

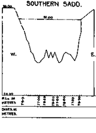
GAUGE - DISCHARGE CURVE.

All observations 1920-1924.



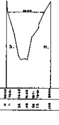
SECTION V.

IFWADDA LAGOON
SAME LINE AS SECTION 1.
PROPOSED SITE OF
SOUTHERN SADD.



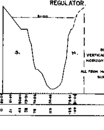
SECTION W.

SOUTH DEBRA MARIAM
CHANNEL,
SAME LINE AS SECTION 1.



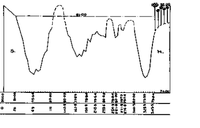
SECTION X.

WEST END OF SOUTH DEBRA
MARIAM CHANNEL AT KILO 0·0.
THE PROPOSED SITE OF THE
REGULATOR.



SECTION Y.

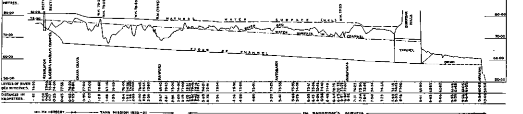
NORTH DEBRA MARIAM CHANNEL,
SAME LINE AS IN SECTION 1.
PROPOSED SITE OF NORTHERN SADD.



SECTION Z.

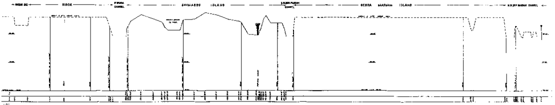
LONGITUDINAL SECTION ALONG THE LINE OF THE PROPOSED CHANNEL, TUNNEL AND DRAIN.

HORIZONTAL SCALE 1:25,000 VERTICAL SCALE 1:500.

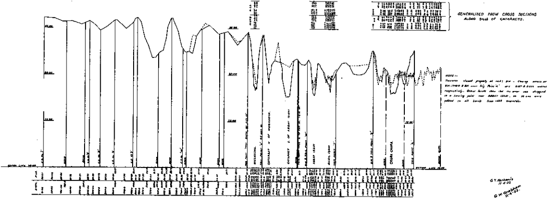


S.Y.K.
22-11-24.

SECTION No. 1



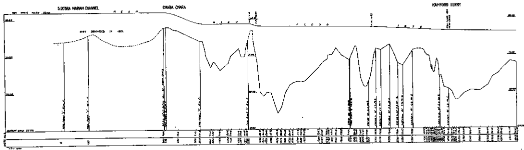
SECTION ACROSS THE OUTLETS OF LAKE TANA.
HORIZONTAL SCALE 1:2000 — VERTICAL SCALE 1:100.



SECTION ALONG UPPER REEF AND ACROSS CATARACTS.

HORIZONTAL SCALE 1:5,000 – VERTICAL SCALE 1:100.

SECTION Nº 5.



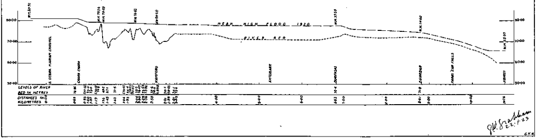
SECTION ALONG ABBAI, SOUTH DEBRA MARIAM CHANNEL TO KAMFORO.

HORIZONTAL SCALE 1:5,000 – VERTICAL SCALE 1:100.

SECTION Nº 4.

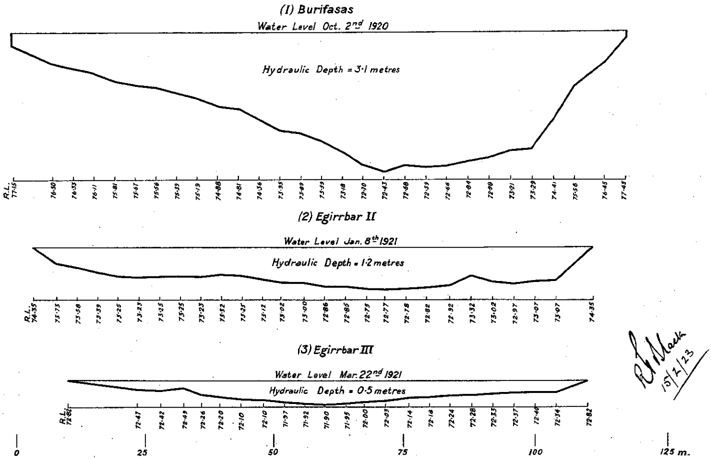
SECTION ALONG ABBAI — SOUTH DEBRA MARIAM CHANNEL TO JIRMIDI.

HORIZONTAL SCALE 1:25,000 — VERTICAL SCALE 1:500.



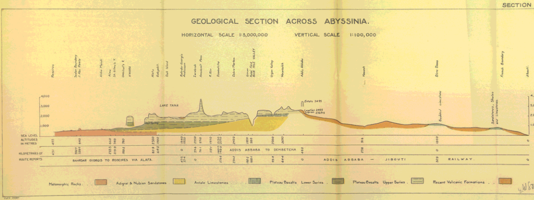
No 5.

DISCHARGE SITE SECTIONS



Horizontal scale 1:500. Vertical scale 1:100.

S. of E. 25/172.



SECTION No 6.
GEOLOGICAL SECTION ACROSS ABYSSINIA.
HORIZONTAL SCALE 1:3,000,000
VERTICAL SCALE 1:100,000
Roseires
Sudan Boundary
J. Abu Ramla
Abba Mendi
Alma
Sh Gilmo's V.
Uabibal's V.
KWARA
Alafa
Gobgobit.
Dek Island
Bahrdar Georgis
Andassan
Zarabruk
Amedami Pass
R. Bir
Dembetcha
Debra Markos
Ginan
Kutai Ford
BLUE NILE VALLEY
Urgan Valley
Wanabelch
Addis Abbaba
Hawash
Dire Dawa
Bouderal Limestone
Sandstones, Shales and Limestones
French Boundary
Jibouti
LAKE TANA
Hot Spring
Entoto 3495
Legation 2455
Station 2369
4,000
3,000
2,000
1,000
SEA LEVEL
ALTITUDES IN METRES
KILOMETRAGES OF ROUTE REPORTS
ADDIS ABBABA TO DEMBETCHA
BAHRDAR GIORGIS TO ROSEIRES VIA ALAFA.
ADDIS ABBABA — JIBOUTI RAILWAY.
Metamorphic Rocks
Adigrat & Nubian Sandstones
Antalo Limestones
Plateau Basalts Lower Series
Plateau Basalts Upper Series
Recent Volcanic Formations